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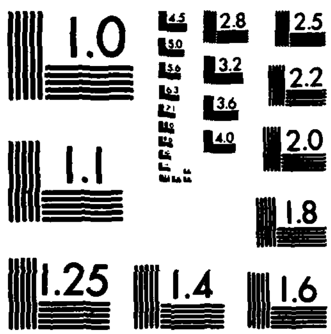

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A Computer Code to Calculate Emission and Transmission of Infrared Radiation Through Non-Equilibrium Atmospheres

R. D. SHARMA
R. D. SIANI
M. K. BULLITT
P. P. WINTERSTEINER

8 July 1983

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A computer code that calculates infrared radiance in the upper atmosphere has been developed. The code, for limb-looking geometry and conditions where local thermodynamic equilibrium may not hold, utilizes individual ro-vibrational transitions to calculate the optical thicknesses along each segment of the line-of-sight path. The formulation of the problem is given, as is the means of using the program and the procedure for obtaining input data from certain data bases. Appendices contain program listings and two examples.

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A Computer Code to Calculate Emission and Transmission of Infrared Radiation Through Non-Equilibrium Atmospheres

1. INTRODUCTION

The Air Force Geophysics Laboratory is in the process of developing a comprehensive computer code, NLTE, for calculating the radiance due to infrared-active species in the upper atmosphere. In particular, the code deals with atmospheric conditions in which local thermodynamic equilibrium (LTE) cannot be assumed; that is, conditions under which the populations of vibration-rotation states cannot (necessarily) be given by a Boltzman-distribution with the kinetic temperature. Moreover, it does a line-by-line calculation, rather than a band calculation, using the properties of individual rotational lines obtained from the AFGL Atmospheric Absorption Line Parameters Compilation.[1,2,3,4] The output is the integrated radiance from each line under consideration. The individual lineshapes can also be obtained, if necessary.

At present, the non-LTE conditions are simulated by the use of a vibrational temperature profile. Work is in progress to incorporate into the program computations of the direct physical mechanisms that are responsible for the populations of the excited states. That is, the excitation of infrared-emitting species by sunshine, earthshine, collisions, and photochemical reactions will be used to directly calculate

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(Due to the large number of references cited above, they will not be listed here. See References, page 21.)

the populations of vibrational states rather than using the vibrational temperature profile as input.

The looking geometry is assumed to be horizon-to-horizon. It is therefore parameterized by a tangent height, the lowest altitude along the line-of-sight path.

2. FORMULATION

We consider the path through which a photon has to pass to reach the observer to be made up of a series of slabs. In each of the slabs the kinetic temperature, the vibrational temperature, and the density of the atmospheric constituents in the ground and excited states is assumed to be constant. The altitude of the end points of each slab may not differ by more than 1 km (Figure 1).

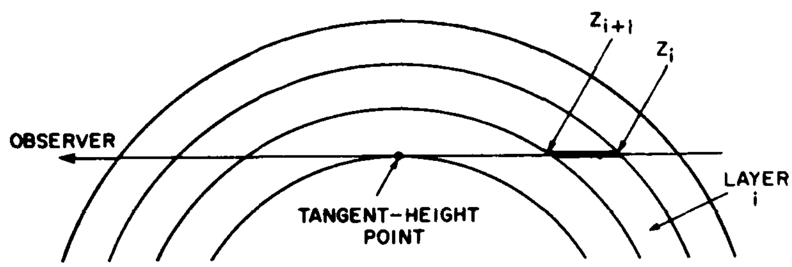

Figure 1. The Line-of-Sight Path Through a Layered Atmosphere, the enhanced segment showing its intersection with the ith layer over a distance $\Delta Z_i = Z_{i+1} - Z_i$

At first glance, it might appear that we are constructing a model for a one-dimensional atmosphere. This, however, is not the case. One can make the slabs as small as desired—so small in fact that the errors may be determined principally by the uncertainties in the input model atmosphere. Nor is there any requirement that the two slabs corresponding to a given altitude on either side of the tangent height point have the same composition.

In the equations that we derive, we will assume that lines for which the intensity is calculated are non-overlapping. That this is a reasonable assumption can be seen from the following argument. The two closest lines in the 15-μm band of the $C^{12}O_2^{16}$ $01^10\text{-}00^00$ transition are Q(2) and Q(4) which are 0.0145 cm^{-1} apart.

Recalling that the Doppler linewidth at 200 K, corresponding roughly to 70 km in altitude, is about 0.0005 cm^{-1}, it can be seen that the separation between the Q(2) and Q(4) lines corresponds to about 30 linewidths. Apart from the accidental overlap of lines of different bands, that may occur rather infrequently, we expect most of the lines to be spaced several linewidths apart. The assumption of non-overlapping lines thus appears reasonable.

We express the radiance in terms of n_ν, the number of photons (of frequency ν cm^{-1}) per wavenumber per unit area per steradian which are observed at a point z along the line-of-sight path per unit time. The change in n_ν in a path length dz is described by

$$\frac{dn_\nu}{dz} = \left[- n_\nu \frac{h\nu_0}{c} \left(n_\ell B(\ell \rightarrow u) - n_u B(u \rightarrow \ell)\right) + \frac{A}{4\pi} n_u \right] f(\nu - \nu_0) \tag{1}$$

where h and c are Planck's constant and the speed of light, n_ℓ and n_u are the number densities of the lower and upper radiating states, $B(\ell \rightarrow u)$ and $B(u \rightarrow \ell)$ are Einstein coefficients for absorption and induced emission, A is the Einstein coefficient for spontaneous emission and f is the normalized lineshape function such that

$$\int_{-\infty}^{\infty} f(\nu - \nu_0)\, d\nu = 1 . \tag{2}$$

In Eq. (1), $n_\nu n_\ell B(\ell \rightarrow u)$ is the term for the absorption of incident photons. $n_\nu n_u B(u \rightarrow \ell)$ is the induced emission term. The factor $(h\nu_0/c)$, which is commonly absent in derivations of this equation, appears because of the fact that n_ν is a photon flux rather than an energy flux, and because ν is in units of cm^{-1} instead of sec^{-1}.

The Einstein coefficients[5] are connected by

$$g_\ell B(\ell \rightarrow u) = g_u B(u \rightarrow \ell) \tag{3}$$

and

$$A = 8\pi h\nu_0^3 B(u \rightarrow \ell) \tag{4}$$

where g_ℓ and g_u are the statistical weights of the lower and upper radiating states. Through use of Eqs. (3) and (4), the definition

---

5. Penner, S.S. (1959) Quantitative Molecular Spectroscopy and Gas Emissivities, Addison-Wesley, Reading, Massachusetts.

$$\gamma \equiv \frac{g_\ell \, n_u}{g_u \, n_\ell} \tag{5}$$

and some algebraic manipulation we see that Eq. (1) can be cast in the form

$$\frac{dn_\nu}{dz} = \frac{h\nu_o}{c} B(\ell \rightarrow u) \, n_\ell \left[-n_\nu (1 - \gamma) + 2 c\nu_0^2 \gamma \right] f(\nu - \nu_0) \, . \tag{6}$$

One can readily see that the $(1 - \gamma)$ factor corrects the simple absorption term (which is proportional to $n_\ell \, n_\nu$) for stimulated emission; the other term in the brackets is the spontaneous emission.

Next we connect the Einstein coefficient to the line strength which is available on the AFGL Line Parameters Compilation.[1] The tabulated line strengths $S(T_s)$ are given for conditions of LTE at the standard temperature T_s, which is 296 K, and are related to $B(\ell \rightarrow u)$ by

$$\frac{h\nu_0}{c} B(\ell \rightarrow u) = \frac{S(T_s)}{P_\ell(T_s)} \left(1 - \exp\left(-C_2 \nu_0 / T_s\right)\right)^{-1} \tag{7}$$

where $C_2 = 1.4388 \text{ K/cm}^{-1}$ is the second radiation constant and $P_\ell(T_s)$ is the probability of finding the lower vibration-rotation state occupied. In general, $P_\ell = n_\ell / n$ where n is the total number density of the specie.

The exponential term in Eq. (7) takes into account the stimulated emission at 296 K, and in fact is simply γ evaluated under conditions of LTE at T_s.

We now define the optical depth, τ_ν, by

$$\frac{d\tau_\nu}{dz} = \frac{h\nu_0}{c} B(\ell \rightarrow u) f(\nu - \nu_0) n_\ell (1 - \gamma) = \frac{S(T_s)}{P_\ell(T_s)} f(\nu - \nu_0) \, n_\ell \, \frac{1 - \gamma}{1 - \exp\left(-C_2 \nu_0 / T_s\right)} \, . \tag{8}$$

Since the quantities f, n_ℓ, and γ are (by assumption) constant within the confines of each slab, the optical depth of the ith slab is

$$\Delta\tau_{\nu i} = \tau_\nu(Z_{i+1}) - \tau_\nu(Z_i) = \frac{S(T_s)}{P_\ell(T_s)} f(\nu - \nu_0) \, n_\ell \, \frac{Z_{i+1} - Z_i}{1 - \exp(-C_2 \nu_0 / T_s)} (1 - \gamma) \, . \tag{9}$$

(The subscript i is implied for f, n_ℓ, and γ.) Expressing n_ℓ in terms of the total number density, this becomes

$$\Delta\tau_{\nu i} = \left[S(T_s) \frac{P_\ell(T)}{P_\ell(T_s)} \frac{1-\gamma}{1-\exp(-C_2\nu_o/T_s)} \right] f(\nu-\nu_0)\, n_\ell\, \Delta Z_i \, . \tag{10}$$

The term in square brackets now represents the line strength for conditions prevailing in the slab, including corrections for stimulated emission, and this times $f(\nu - \nu_0)$ is the conventional absorption coefficient $k(\nu)$.[1] $P_\ell(T)$ must be evaluated with the understanding that non-LTE conditions prevail, in general; the same applies to γ. Both these quantities therefore actually depend on the vibrational temperature as well as the kinetic temperature of the slab.

To complete the analysis one combines Eqs. (6) and (8) to give

$$\frac{dn_\nu}{d\tau_\nu} = \left[-n_\nu + 2c\nu_0^2 \frac{\gamma}{1-\gamma} \right] . \tag{11}$$

This equation can easily be integrated across a slab. The solution is

$$n_\nu(Z_{i+1}) = n_\nu(Z_i)\, e^{-\Delta\tau_{\nu i}} + 2c\nu_0^2 \frac{\gamma_i}{1-\gamma_i} (1 - e^{-\Delta\tau_{\nu i}}) \tag{12}$$

where the slab-dependence of γ is finally made explicit with the subscript. In Eq. (12), the first term represents the absorption within the ith slab of radiance incident upon it at Z_i; and the second term represents the contribution from the ith slab alone. The strategy of the program is now clear. The boundary condition at the far horizon is $n_\nu(Z_i) = 0$ for all frequencies. Using that as the starting point, one calculates the radiance at the near end of each slab from Eq. (12) until the observer's end of the line-of-sight path is reached. One thus obtains a line profile for the observed radiance. This profile is integrated over frequency to get the radiance for the line in question. At the end the result is converted to units of W/cm^2-steradian.

NLTE also calculates the integrated radiance to be expected if the line is thin—that is, if $\Delta\tau_{\nu i}$ is always much less than unity for that line. The determination of whether a line actually is thin is made by comparing this result with the integral over the computed lineshape. Agreement within 5 percent defines a "thin" line.

The program adds the integrated radiance from all the lines it selects from the line-file provided by the user. It performs this operation for each looking geometry specified, starting with the lowest tangent height. For each tangent height after the first, as the computation proceeds it checks to see whether the line under consideration has been found to be thin for paths characterized by a lower tangent height. If it has, it is also assumed to be thin for the current path and all paths characterized

by greater tangent heights. The lengthy profile calculations are thereby avoided for this line, and the integrated intensity is taken to be the "thin" result.

3. USE OF THE PROGRAM

NLTE has been written in ANSI-standard FORTRAN '77. It is still in the process of being developed and made more efficient, and many changes are anticipated. A listing appropriate for radiance from CO_2 is given in the Appendix. At present NLTE requires 65,000 words to compile and execute on the CDC-6600 at AFGL. A high-optimization option should be selected at compile time (OPT = 2) unless changes are being made and the debug package is required. Except for a few seconds of overhead required for initialization, the execute time is nearly proportional to the number of lines used. It is usually also proportional to the number of tangent heights selected, but if many of the lines are thin the execute time can be reduced since fewer computations are required. Selecting the Doppler lineshape instead of the Voigt profile can cut the run time by a factor of three.

NLTE requires information from three data files, one of which is the input stream. These files, which are associated with units 1, 2, and 3, contain miscellaneous program input, an atmospheric profile, and a coded AFGL line file, respectively.

Table 1 lists the miscellaneous program input on unit 1. Three card-images are required, and they are read with list-directed reads. This means that comma or blank delimiters separate the data elements, and there is no need to align the latter in particular columns. All variables of type character must be enclosed in quotes ('). Default values result from blank fields. These are defined by consecutive commas or, in the case of the last fields on a card, by a single slash (/). Example 1 gives a possible data record for Unit 1.

The first of these three cards gives the specie of interest, and three energies which are required. The latter are the energy of the vibrational transition in question, which is needed to calculate γ; the vibrational energy of the lower state, needed for $P_{\ell}(T)$; and the energy of the lowest-energy vibrational transition, needed to calculate the vibrational partition function. The program does not recognize defaults for any of these quantities.

The second card identifies the lines which are used to calculate the radiance, assuming they can be found on the line file. That is, the required frequency range, band, branch, and rotational line designations are specified, and all lines satisfying these requirements are used. The frequency range is given by VMIN and VMAX. The band is specified by the upper- and lower-state quantum numbers, UST and LST; the branch, by BR; and the rotational line by NRQL. Acceptable values of BR are

'P', 'Q', 'R', and 'A', where 'A' implies all branches. Acceptable values of NRQL are integer numbers identifying single lines of a branch; and 999, implying all lines of the selected branch(es).

NDP is a code specifying the lineshape to be used in the computation. A value of 0 causes the Voigt profile to be used; 1 gives the Doppler lineshape.

The program recognizes defaults of 0, 0, and 50000 for NDP, VMIN, and VMAX respectively.

The third card gives the tangent heights which define the looking geometry for each desired case. TANIN is the lowest tangent height, TANF the highest, and INTRVL is the spacing.

Table 1. Miscellaneous Program Information on Unit 1

Quantity	Description	Units	Type	Example
(CARD 1A)				
MOL	Molecular formula		Character	'CO2'
ISO	Isotope code		Integer	626
VIBE	Vib energy of the transition	cm^{-1}	Real	667.3
VIBL	Vib energy of lower state	cm^{-1}	Real	0
VIBQ	Vib energy for partition fn	cm^{-1}	Real	667.3
(CARD 1B)				
BR	Branch (P, Q, or R)		Character	'R'
NRQL	Rotational quantum line		Integer	999
UST	Upper vib state (AFGL not 'n)		Character	'01101'
LST	Lower vib state (AFGL not 'n)		Character	'00001'
NDP	Lineshape option		Integer	0
VMIN	Lowest wavenumber desired	cm^{-1}	Real, int	600
VMAX	Highest wavenumber desired	cm^{-1}	Real, int	750
(CARD 1C)				
TANIN	Initial tangent height	km	Integer	70
TANF	Final tangent height	km	Integer	80
INTRVL	Examination height	km	Integer	5

Example 1 Example of an Input Data Record on Unit 1

```
'CO2', 626, 667.3, 0, 667.3
'R', 999, '01101', '00001'/
70, 80, 5
```

Unit 2 contains the atmospheric profile which is to be used in the radiance calculation. The file providing this information is headed by a single card-image containing identifying comments. Each succeeding card-image contains the information

listed in Table 2, in the format given there. No more than 250 cards, which correspond to successively higher altitudes with a 1-km spacing, may be read in. The lowest altitude must be less than or equal to TANIN. The highest must be greater than or equal to TANF + 50, since the calculations are done using 50 layers.

A procedure for obtaining the atmospheric-profile data files in the form required by NLTE for input on Unit 2 is described in the next section

Unit 3 contains the coded line file. This is needed to determine the absorption and reradiation of energy by each line in the wavelength range under consideration. The contents of such files, and the means of obtaining them from the complete data base which has been developed at AFGL, are given in Section 5.

Table 2. Atmospheric Profile Information on Unit 2

Quantity	Description	Units	Format
A (integer)	Altitude	km	I5
TRTMP	Kinetic temperature	Kelvin	F10.3
ALCOR	Atmospheric pressure	atmos	E12.5
RHO	Density of radiating molecule	cm^{-3}	E12.5
VBTMP	Vibrational temperature	Kelvin	F10.3

4. A PROCEDURE FOR THE ATMOSPHERIC PROFILES

A procedure, called ATMOS, is available at AFGL for the purpose of allowing users to create databases in the format required to input to NLTE on Unit 2. The data presently built into ATMOS are profiles very much like those in the 1976 U.S. Standard Atmosphere. The vibrational profiles can either be read as input to this procedure, or derived in a very simple (but contrived) way from the kinetic temperature. The alternative to reading vibrational temperatures directly is to add or subtract a fixed number of degrees to or from the kinetic temperature. Interpolation procedures are built in so that input data for the vibrational temperature are not needed at intervals as closely spaced (1 km) as they are on output.

The procedure, ATMOS, is in a very preliminary stage of development. In the future, its data base will be expanded to include various standard atmospheric profiles and some other features as well. However, it can be used in its present form on the AFGL central computer system, as shown in Example 2.

ATMOS requires user input at two places: the BEGIN card and the data card following the end-of-record in the input stream. Also, if vibrational profiles are to be read in, a logical file called TAPE4 must be attached. The BEGIN card has two parameters which, if selected, cause the output data file to be cataloged as a

permanent file. The parameters are PFN and NAME, and are used in the example. It is acceptable to omit them completely, in which case the form is simply BEGIN, ATMOS, P, and the data are not saved on a permanent file. In either case, the first ATTACH card should be used exactly as in the example.

The data card should contain six quantities, listed in Table 3. They are read with a list-directed read, discussed above. Most of them are variables of type character, and must therefore be enclosed in quotes. MOL specifies the radiating molecule. Acceptable values of DORN are 'DAY' or 'NIGHT', reflecting the fact that some species' density profiles have diurnal variations. HMIN and HMAX are the minimum and maximum altitudes of interest.

Table 3. Input Data for the Procedure, ATMOS

Variable	Description	Type	Default
MOL	Molecular Formula	Character	
DORN	Day or night profile	Character	'NIGHT'
HMIN	Lowest altitude (km)	Integer	0
HMAX	Highest altitude (km)	Integer	250
CODE	Code for vib temp	Character	'ADD'
FMT	Format for read, or number of degrees to add	Character	'(I5, F10. 3)' '0'

EXAMPLE 2 Use of the Procedure, ATMOS

```
USER1, T30.                                        1234      USER
ATTACH(P, PROCFILE, ID=WINTERS, MR=1)
ATTACH(TAPE4, USERSFILE, ID=USER, MR=1)
BEGIN(ATMOS, P, PFN=OUTPUTFILE, NAME=USER)
EOR
'CO2', 'NIGHT', 70, 190, 'READ', '(I5, 34X, F10. 3)'
```

CODE and FMT have different forms depending on whether the vibrational temperature profile is to be read from TAPE4, or the vibrational temperature profile is to be determined from the kinetic temperature profile. Meaningful values for CODE are 'READ' and 'ADD'. Anything else causes the vibrational temperature to be set equal to the kinetic temperature everywhere.

If CODE is read as 'READ', the vibrational temperature is read in a user-selected format, given by FMT. Each card-image on TAPE4, except for a header card containing identifying information, should contain an altitude and a vibrational temperature in that order. FMT should then specify two fields, one integer and one real, for reading these quantities. The default value of FMT is '(I5, F10. 3)', but inside the quotes and parentheses, which are required, any format is acceptable.

If CODE is read as 'ADD', FMT must be a character representation of the number of degrees to add to the kinetic temperature. Possible values are '+10', '50', '0', and '-50'. Default is '0'.

5. THE AFGL ATMOSPHERIC ABSORPTION LINE PARAMETERS COMPILATION

For many years, AFGL has maintained and continually updated its own compilation of atmospheric absorption line parameters for transitions from the millimeter region through the visible. These are described in various publications.[1-4] The compilation is the responsibility of Dr. L. S. Rothman, AFGL/OPI.

For users of the AFGL computer system, the data reside on a disk pack in the CDC-6600 computer center. For workers at other installations, the compilation is available on two magnetic tapes. (It is also accessible on two CC tapes at AFGL, but use of the disk pack is preferable.) The compilation was originally developed in two parts. The "Main" compilation contained data from the principal sources of atmospheric infrared absorption. These molecules, corresponding to a gas code of 1 through 7, are H_2O, CO_2, O_3, N_2O, CO, CH_4, and O_2 respectively. The trace-gas file contained data for the molecules whose codes are 8 through 28.[3] In fact, this division still exists on the magnetic tape compilations. A merged line file was recently written to a single disk pack, however, making all the data available (at AFGL) by use of simple procedures.

The data exist in card-images on the pack and tapes, with one card-image corresponding to each transition. There are almost 300, 000 transitions (lines) in all, arranged in order of increasing wavenumber. They are grouped in files spanning 100 wavenumbers, each one divided into records containing up to 250 lines (pack) or 40 lines (tapes). On the pack the files are in buffered binary form; on the tapes, buffered BCD.

The data available for each transition are given in Table 4.[1] There are several programs available for accessing subsets of the complete compilation and making them available in particular formats for specific purposes (for example, input to the LTE radiance program, FASCODE[6]). The formatting listed in Table 4 is the output specification of a procedure, WRITE, written by Dr. Rothman to obtain a coded line file from the disk pack. Generally, subsets of the complete data set are located according to particular (1) frequency ranges, (2) molecules, (3) isotopes, and

6. Clough, S.A., Kneizys, F.X., Rothman, L.S., and Gallery, W.O. (1981) Atmospheric Spectral Transmittance and Radiance: FASCOD1B, AFGL-TR-81-0269, AD A104832; also SPIE 277 (Atmos Transmission) 152-166.

(4) vibrational bands. However, by reading the line file and checking any of the parameters given, one can make a selection based on other criteria as well.

Table 4. Line-File Data for Each Transition

Format	Symbol	Line-File Datum
F10.4	ν	Resonant frequency (cm-1)
E10.3	S	Line intensity at 296 K (cm-1/(molecule-cm2))
F5.4	α	Halfwidth (air broadening) (cm-1/atmos)
F10.3	E''	Energy of the lower state (cm-1)
2A8, A10, A9		Quantum numbers, line identifiers
I3		Entry code for these data
I4	ISO	Isotope code
I3	MOL	Gas code

The meaning of the physical data (frequency, and so on) listed in Table 1 is self-evident. The quantum numbers are discussed in Reference 1 (and, to a small extent, below). The entry code is usually irrelevant for the user. The gas code is an integer between 1 and 28, as mentioned above. The isotope code is also explained in Reference 1. It is a string of integers representing the last digit in the atomic weight of each atom, given in the order in which the atoms exist in the molecule. For example, the main isotope of CO_2 is identified by the code 626, since the molecule consists of atoms of atomic weight 16, 12, and 16.

5.1 Obtaining Files From the Disk Pack

The procedure WRITE, mentioned above, is the easiest way for users at AFGL to obtain data from this compilation. Example 3 gives a control-card sequence which obtains, catalogs on permanent file, and lists all ozone lines between 2000 and 2020 cm^{-1}. For any job using this procedure, the first three cards must be prepared exactly as in the example, except for the user's name and problem number, the specification of the logical file name (P) and possibly the time allocated to the job. The BEGIN card contains optional parameters, described below, which determine the disposition of the information acquired from the compilation. The data card(s) following the end-of-record (EOR) provide the information the procedure requires to identify the desired lines.

The information to be taken from the data cards is listed in Table 5. Each card is read with a list-directed read, which means that the data fields (eight in number) should be separated by comma delimiters and no attention need be paid to the columns used for each field. Default values result from blank fields (consecutive commas). After the last field containing a non-default value, a slash (/) can be used

to terminate data input for that card. Either the slash or a sufficient number of commas to define each field must be used. All input data of type character must be surrounded by quotes, like 'O3' in Example 1. Leading blanks inside the quotes will give unpredictable results. Anywhere else, blanks are irrelevant.

EXAMPLE 3 Use of the Procedure WRITE

```
USER1, T30, CM50000, STMFA, PK.                              1234     USER
ATTACH(P, PROCEDURES, ID=ROTHMAN, MR=1)
MNT(VSN=FAS53, SN=FASPK)
BEGIN(WRITE, P, PFN=OZONELINES, NAME=USER, COPFIL=YES)
EOR
2000, 2020, 'O3',,,,,'PFILE'
```

Table 5. Input Data for the Procedure, WRITE

Datum	Quantity	Type	Default
V1, V2	Frequency range (cm-1)	Integer or real	
MOL	Molecular formula	Character	All molecules
ISO	Isotope code (Reference 1)	Integer	All isotopes
UST, LST	Band quantum numbers	Character	All branches
SCRIT	Threshold strength	Real	All strengths
DISPOS	File disposition code	Character	List only

V1 and V2 must be specified, as there is no default. MOL is an alphanumeric symbol giving the molecular formula. ISO is the isotope code explained earlier, UST and LST are the upper- and lower-state quantum numbers of the vibrational band desired. The quantum numbers are different for different molecules, and their meaning is discussed in Reference 1. For the purposes of WRITE, one enters consecutive digits inside the quotes, for example '11101'.

SCRIT is an intensity threshold. Lines which are weaker than this threshold are ignored. Because of the small magnitudes involved, an E descriptor should be used.

The data selected by the program can either be listed on OUTPUT or written to TAPE8, which is later made into a permanent file. DISPOS is a code used to select the desired disposition. Entering either 'PFILE' or 'PUNCH' in this field causes TAPE8 to be written. Anything else invokes the list option. One can list some data and save other data by entering different disposition codes on different cards.

Lines satisfying the requirements of each separate data card are frequency-ordered on whichever file they are directed to, OUTPUT or TAPE8. However, lines from one data card will always follow those from preceeding cards. If the frequency ranges are increasing and do not overlap, frequency-ordering is preserved.

Otherwise, for TAPE8 only, a SORT/MERGE option (see below) can be specified on the BEGIN card to restore frequency-ordering.

The BEGIN card invokes the procedure WRITE (which is found on logical file P in our example). It allows up to four optional parameters which are used for three separate purposes: to preserve the frequency-ordering on TAPE8, as mentioned above; to give the permanent file name and user identification required for cataloging TAPE8; and to cause the information on TAPE8 to be copied to OUTPUT. The form of each of these parameters is KEYWORD=VALUE, where KEYWORD is fixed and VALUE is supplied by the user. Table 6 describes these parameters. PFN and NAME should be either both be specified, or neither. The parameters can be entered in any order following the logical file name. Parameters which are omitted assume default values, the effect of which is given in Table 6.

Table 6. Parameters for the Procedure, WRITE

Keyword	Value	Default
SORTM	YES	No SORT/MERGE
PFN	Permanent File Name	No catalog is done even if PFILE is specified on some data cards
NAME	User's ID	
COPFIL	YES	No list of TAPE8

It is possible to invoke WRITE more than once in a single job, with different parameters, so long as TAPE8 is returned after each usage and so long as one data record is provided for each usage.

The WRITE output specification given in Table 4 is that used on TAPE8. It may change slightly for certain frequency ranges, since sometimes more significant figures are available than this particular format allows. The field widths are always the same, however. On OUTPUT, when the list option is selected, the fields are spread out for ease in reading and to make space for annotation.

Example 4 contains a small subset of lines from the 11101-00001 band of CO_2, in the format assigned by WRITE and described above. Example 5 gives a possible, albeit unusual, set of requirements for linefiles, with many different forms used on the data cards. Only three sets of lines are written to TAPE8, and these are then ordered before being cataloged and copied. The second call to WRITE produces the lines of which Example 4 is a subset.

EXAMPLE 4 Portion of a Coded File from WRITE

```
2075.2960 7.868E-24.0770    2.341  11101 00001   P  2 482 626 2
2076.8632 3.363E-23.0770    2.341  11101 00001   Q  2 482 626 2
2076.8788 5.894E-23.0770    7.804  11101 00001   Q  4 482 626 2
2076.9034 8.166E-23.0760   16.389  11101 00001   Q  6 482 626 2
2076.9369 1.009E-22.0750   28.095  11101 00001   Q  8 482 626 2
2076.9793 1.160E-22.0750   42.922  11101 00001   Q 10 482 626 2
2077.0308 1.265E-22.0740   60.871  11101 00001   Q 12 482 626 2
2077.0912 1.325E-22.0740   81.940  11101 00001   Q 14 482 626 2
2077.1607 1.340E-22.0730  106.130  11101 00001   Q 16 482 626 2
2077.2393 1.316E-22.0720  133.439  11101 00001   Q 18 482 626 2
2077.3270 1.258E-22.0720  163.868  11101 00001   Q 20 482 626 2
2077.4239 1.173E-22.0710  197.416  11101 00001   Q 22 482 626 2
2077.5299 1.069E-22.0710  234.083  11101 00001   Q 24 482 626 2
2077.6373 1.252E-23.0780    0.000  11101 00001   R  0 482 626 2
```

EXAMPLE 5 Possible Usage of the Procedure WRITE

```
USER2,T30,CM50000,STMFA,PK.                          1234        USER
ATTACH(P,PROCEDURES,ID=ROTHMAN,MR=1)
MNT(VSN=FAS53,SN=FASPK)
BEGIN(WRITE,P,SORTM=YES,PFN=MISCLINES,NAME=USER,COPFIL=YES)
RETURN(TAPE8)
BEGIN(WRITE,P,PFN=CO2LINES,NAME=USER)
EOR
1220.000,    1221.000/
1220,1221,'H2O'/
1220    , 1221, 'H2O  ' ,181  /
1220, 1221,,,'100','000'/
1220,1221,,,,,5.E-22/
1220,1221,,,,,5.E-22,'PFILE'
1220,1221,,,'00000111',00000000',,'PUNCH'
1220., 1221,,211,,,,'PFILE'/
EOR
  2000,2173,'CO2',626,'11101','00001',,'PFILE'
```

5.2 Obtaining Files From the Magnetic Tapes

Users who do not have access to the disk pack can obtain the line-file data from the two magnetic tapes. The tapes contain files spanning 100 wavenumbers and each file is split into records containing up to 40 transitions (the last record generally being shorter). Each card-image consists of eight 60-bit words, and there is a single word at the beginning of each record specifying the number of transitions on the record. The typical record therefore consists of 321 words.

The data on the tapes are the same as is given in Table 4, and in fact the format appropriate for decoding the record is exactly that given in Table 4 except for the 35 characters specifying the quantum numbers and line identifiers. The format for this portion of the card-image depends on the molecule in question and is described in Reference 1. In this context (magnetic tapes) the ordering and formatting given

in Reference 1 is correct, unlike that of the new disk pack where uniformity dictated certain changes.

In order to obtain a line file the coded records containing the data must somehow be read into arrays, and the data must be checked to see if they are included in the user's desired subset. In other words, a program to serve the function of procedure WRITE is required. On CDC systems, each record can be read with a BUFFER IN statement. One can then use the internal file feature of FORTRAN '77 as a means of converting character information to numerical information. This feature utilizes a variable or array of type character as the internal file. Formatted read and write operations, to and from this region of memory, perform the conversion. This approach is superior to the use of DECODE for several reasons, one of which is that it is ANSI-standard and hence available to all FORTRAN '77 users.

Example 6 gives a small portion of a possible FORTRAN program which could be used to examine the line-file data on a CDC system. The tape is identified with TAPE5. After the record is buffered in, the first word, A(1), is checked to determine the number of transitions on the record. The internal file used here is the variable C. Then, using array B as the internal file, the data for all transitions are read into arrays according to FORMAT statement 102. All the information is now in numerical form and can be manipulated with normal arithmetic operations, except the 35 characters of identifying information which are left in character form and can therefore be compared only with other character variables.

The loop DO 300 performs simple comparisons for each line to see if the data satisfy the user's criteria. The third and fourth IF statements compare substrings of the Ith element of CH with the codes for the desired branch, defined in the DATA statement.

This sketchy example, with its data and formats "hardwired" in, is obviously insufficient to duplicate the capability of procedure WRITE, but the basic idea can be developed into something considerably more general. Note that there is no need to dump all of the 35 characters of identifying information into a character array. Some of that information, such as the upper- and lower-state quantum numbers, is in the form of digits and could be converted to integers for arithmetic comparisons. Alternatively, any or all of it could be ignored altogether.

This also neglects the matter of file positioning—that is, skipping files and records until the record containing the lowest desired frequency is in position to be read. This is obviously desirable, to avoid reading and simply discarding hundreds or thousands of records. Since files span 100-wavenumber regions, the number of files to skip is easily determined. For example, to get lines in the region 650-750 cm^{-1}, six complete files are skipped: SKIPF(TAPE5, 6, 17, C). If, in addition, the lines at 650 cm^{-1} are known to be in the (N+1)st record, N records can then also be

skipped within the seventh file): SKIPF(TAPE5, N, 1, C). Otherwise, as is generally the case, one must read each record of the correct file to discover its range of wavenumbers.

For users at installations without CDC equipment, the procedures for reading the coded tape are likely to be quite different. In particular, the different word sizes and character codes have to be accounted for.

EXAMPLE 6 Portions of a possible FORTRAN code for reading magnetic tape line files.

```
      PROGRAM X
      CHARACTER*80 B(40)
      CHARACTER*35 CH(40)
      CHARACTER*10 C, BRDES(2)
      DIMENSION A(321), V(40), STS(40), ALF(40), EDP(40), ISO(40), MOL(40)
      DATA BRDES/' 0 1 1 0 1',' 0 0 0 0 1'/
      OPEN(5)
  100 FORMAT(8A10)
  101 FORMAT(I10)
  102 FORMAT(F10.4,E10.3,F5.3,F10.3,A35,3X,14,I3)
      .
      .
      MDES = 2
      IDES  = 626
  150 BUFFER IN (5,0) (A(1), A(321))
      IF(UNIT(5))200,900,900
C
C     CHECK N, THE NUMBER OF LINES ON THIS RECORD
C
  200 WRITE(C,100)A(1)
      READ(C,101)N
C
C     DECODE THE REST OF THE RECORD
C
      M = 8*N + 1
      WRITE(B,100)(A(I),I=2,M)
      READ(B,102)(V(I),STS(I),ALF(I),EDP(I),CH(I),ISO(I),MOL(I),I=1,N)
C
C     CHECK FOR THE DESIRED MOLECULE (MDES), ISOTOPE (IDES) AND
C       BRANCH (BRDES)
C
      DO 300 I = 1,N
      IF(MOL(I).NE.MDES)GO TO 300
      IF(ISO(I).NE.IDES)GO TO 300
      IF(BRDES(1).NE.CH(I) (3:12))GO TO 300
      IF(BRDES(2).NE.CH(I) (18:27)GO TO 300
C
C     STORE THE DATA FOR THIS LINE
C
      .
      .
  300 CONTINUE
      GO TO 150
      .
      .
C     ERROR BRANCHES
C
  900 CONTINUE
      .
      .
      .
```

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Appendix A

Program Listings

```
      PROGRAM NLTE
      REAL NVZ
      INTEGER TANIN,TANF,A,NQL,HTS,DEGV,FLAG
      CHARACTER*1 BR,BRNCH(546),BCH
      CHARACTER*5 XX(3),MCL
      CHARACTER*10 UST,LST,US,LS,MSC(8)
      DIMENSION NVZ(101,4),DVV(101)
      DIMENSION TRTMP(250),VETMP(250),RHO(250),CRAT(250),ALCCR(250)
      DIMENSION ZZ(250,4),GBB(250),S(250),CWID(250),VGT(250)
      DIMENSION JT(546),RQL(546)
      DIMENSION V(546),STS(546),ALF(546),EOP(546)
      DIMENSION RAD(4),SUMRAD(4),HTS(4),THINR(4),FLAG(4)
C
      OPEN(1,FILE='INPUT')
      OPEN(2)
      OPEN(3)
      OPEN(4,FILE='OUTPUT')
C
    1 FORMAT(//)
    2 FORMAT(1X)
C
C     ****************************************************************
C
C     DEFINE ALL CONSTANTS AND INITIAL VALUES
C        EARTHR = EARTH'S RADIUS (KM)
C        TS = STANDARD LINE STRENGTH TEMPERATURE (K) FOR AFGL TAPE
C        BOLTZ = BOLTZMAN'S CONSTANT (ERGS/DEG)
C        BK = BOLTZMAN'S FACTOR (CM-1/DEG).    THIS FACTOR IS NEEDED IN
C             EXPRESSIONS LIKE EXP(-H*C*V/(BOLTZ*T)) WHERE V IS IN CM-1
C             AND T IS SOME TEMPERATURE. LATER THE TEMPERATURE PROFILES
C             ARE PREMULTIPLIED BY BK TO SAVE SOME OPERATIONS.
C        BST = BOLTZ*TS/(H*C)
C        C =  SPEED OF LIGHT (CM/SEC)
C        H =  PLANCK'S CONSTANT (ERG-SEC)  AFTER ITS INITIAL USE, MULTIPLY BY
C             10**-7 TO GET MKS UNITS, WHICH GIVES THE EVENTUAL RADIANCES IN
C             TERMS OF WATTS RATHER THAN ERGS/SEC.
C
      A2 = SQRT(ALOG(2.0))
      EARTHR = 6361.
      TS = 296.0
      BOLTZ = 1.381E-16
      C = 2.9979E+10
      H = 6.6262E-27
      BK = BOLTZ/(H*C)
      BST = TS*BK
      H = H*1.0E-07
      NLYR = 50
      XX(1) = '(ALL)'
      XX(2) = '     '
      XX(3) = '     '
C
C     ****************************************************************
C
C     READ IN MODELLING DATA FROM CARDS---UNIT 1
C
C     CARD 1A  SPECIES CARD---LIST-DIRECTED READ, NO BLANK DEFAULTS
C                  MCL  = RADIATING MOLECULE (INPUT AS 'CO2', ETC.
```

```
C                                                INCLUDING QUOTES)
C                    ISO  = ISOTOPE CODE
C                    VIBE = VIBRATIONAL ENERGY (CM-1) OF THE RADIATIVE
C                           TRANSITION
C                    VIBL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE
C                    VIBQ = VIBRATIONAL QUANTUM (CM-1) WHICH ENTERS
C                           THE EXPRESSION FOR THE PARTITION FUNCTION
C
C     CARD 1B   SPECIES CARD
C                    BR   = BRANCH (P, Q, OR R)
C                    NROL = ROTATIONAL QUANTUM LINE
C                    UST  = THE UPPER STATE INDICES (AFGL LINE FILE NOTATION)
C                    LST  = THE LOWER STATE INDICES (AFGL LINE FILE NOTATION)
C                    NCP  = LINESHAPE OPTION% 0 (DEFAULT) = VOIGT, 1 = DOPPLER
C                    VMIN = LOWER LIMIT ON THE WAVENUMBER OF THE DESIRED LINES
C                    VMAX = UPPER LIMIT ON THE WAVENUMBER OF THE DESIRED LINES
C
C     WHEN BR = A, ALL P, Q, AND R BRANCHES ARE EVALUATED
C     WHEN NROL = 999 ALL QUANTUM LINES ARE EVALUATED
C
C     DEFAULT ON VMIN IS ZERO; THAT IS, THE LOWEST-WAVENUMBER LINES ON
C     THE FILE ARE EVALUATED. DEFAULT ON VMAX IS A NUMBER GREATER THAN
C     ANY CONCEIVABLE WAVENUMBER ON A LINE FILE, 50000 CM-1.
C
C     INDIVIDUAL LINES CAN BE SELECTED BY SETTING BR TO P, Q, OR R
C     AND NROL TO THE DESIRED LINE NUMBER.
C
C     CARD 1C   TANGENT HEIGHT CARD---UNIT 1---LIST-DIRECTED READ, NO DEFAULTS
C                    TANIN  = INITIAL TANGENT HEIGHT (KM)
C                    TANF   = FINAL   TANGENT HEIGHT (KM)
C                    INTRVL = EXAMINATION INTERVAL   (KM)
C
C*****1A
C*****
      READ  (1,*)  MOL,ISO,VIBE,VIBL,VIBQ
      WRITE (4,11) MOL,ISO,VIBE,VIBL,VIBQ
   11 FORMAT(1H1,4X,'MOL   = ',A3,/,5X,'ISO = ISOTOPE CODE =',I4,/,5X,
     1'VIBE = VIBRATIONAL ENERGY (CM-1)  OF THE TRANSITION  =',F9.3,/,
     25X,'VIBL = VIBRATIONAL ENERGY (CM-1)  OF THE LOWER STATE =',F9.3,
     3/,5X,'VIBQ = VIBRATIONAL QUANTUM (CM-1) (FOR PARTITION FUNCTION)',
     4' =',F9.3)
      WRITE(4,2)
C
C     CALL MOLEC TO ESTABLISH THE MOLECULAR WEIGHT AND OTHER PARAMETERS
C     ASSOCIATED WITH THE RADIATING MOLECULE
C
      CALL MOLEC(MOL,ISO,MOLWT,DEGV,FROT,TEXP)
C
      WRITE(4,12)MOLWT,DEGV,FROT,TEXP
   12 FORMAT(5X,'MOLWT =',I3,/,5X,
     1'DEGV  =',I3,/,5X,
     2'FROT  =',F4.1,/,5X,
     3'TEXP  =',F4.2)
C
      WGT = FLOAT(MOLWT)/6.02486E+23
C
      NCP = 0
```

```
      VMIN = 0.0
      VMAX = 5.0E+04
C*****1B
C*****
      READ(1,*) BR,NRQL,LST,LST,NDF,VMIN,VMAX
      WRITE(4,1)
      IF(BR.EQ.'A')XX(2) = XX(1)
      IF(NRQL.EQ.999)XX(3) = XX(1)
      I = INT(VMIN)
      N = INT(VMAX)
      MSG(1) = 'VOIGT'
      IF(NDF.EQ.1)MSG(1) = 'DOPPLER'
      WRITE(4,21)I,N,MOL,ISO,UST,LST,BR,XX(2),NRQL,XX(3),MSG(1)
   21 FORMAT(5X,'PROGRAM WILL SEARCH THE LINE FILE BETWEEN',I5,' AND',
     1I6,' CM-1 FOR LINES OF ',A3,/,5X,
     2'ISOTOPE =',I4,/,5X,
     3'BAND     =',1X,A5,' - ',1X,A5,/,5X,
     4'BRANCH  =',1X,A1,1X,A5,/,5X,
     5'LINE #   =',I2,1X,A5,/,5X,
     6A8,'= LINESHAPE OPTION SELECTED')
      WRITE(4,1)
C
C*****1C
C*****
      READ (1,*) TANIN,TANF,INTRVL
      WRITE (4,61) TANIN,TANF,INTRVL
   61 FORMAT(5X,'INITIAL TANGENT HEIGHT (KMS) =',I5,/,5X,
     $'FINAL TANGENT HEIGHT (KMS)    =',I5,/,5X,
     $'EXAMINATION INTERVAL (KMS)    =',I5)
      WRITE(4,1)
C
C     ***********************************************************************
C
C     CARD 2  ATMOSPHERE CARDS---UNIT 2
C
C     THE FIRST CARD IS AN 80-CHARACTER IDENTIFYING MESSAGE WHICH IS
C     SIMPLY READ AND PRINTED. SUCCESSIVE CARDS EACH CONTAIN, IN FOR-
C     MATS GIVEN BELOW:
C
C                         A        = ALTITUDE (KMS) (INTEGER VARIABLE)    I5
C                         TRTMP(A) = TRANSLATIONAL TEMPERATURE (K)        F10.3
C                         ALCOR(A) = ATMOSPHERIC PRESSURE (ATMOSPHERES)   E12.5
C                         RHO(A)   = DENSITY OF RADIATING MOLECULE (CM-3) E12.5
C                         VETMP(A) = VIBRATIONAL TEMPERATURE (K)          F10.3
C
C*****2
C*****
      READ(2,63)MSG
      WRITE(4,64)MSG
      WRITE(4,62)MOL
   62 FORMAT(7X,'ALT',5X,'TR TEMP   VB TEMP',6X,'TOT PRESS',3X,A5,
     1'DENSITY',/,6X,'(KM)',2(7X,'(K)'),5X,'(ATMOS)',7X,'(CM-3)',/)
   63 FORMAT(8A10)
   64 FORMAT(//,4X,'ATMOSPHERE---"',8A10,'"',/)
C
C*****2
C*****
```

```
   70 READ (2,80,END=90) A,TRTMP(A),ALCOR(A),RHO(A),VBTMP(A)
   80 FORMAT(I5,F10.3,2F12.5,F10.3)
      WRITE (4,81) A,TRTMP(A),VBTMP(A),ALCOR(A),RHO(A)
   81 FORMAT(5X,I5,2X,2F10.3,2X,2F14.6)
      GO TO 70
C
C     THE ARRAY RHO IS CONVERTED TO THE GEOMETRIC MEAN DENSITY IN THE
C     LAYER WHOSE BOUNDARIES ARE A AND A + 1 AND STORED WITH INDEX A.
C
C     THE ARRAYS TRTMP AND VBTMP ARE CONVERTED TO AVERAGE TEMPERATURES IN
C     THE LAYER WHOSE BOUNDARIES ARE A AND A + 1. THESE AVERAGE TEMPERATURES
C     ARE ALSO MULTIPLIED BY BK (SEE COMMENT AT BEGINNING: THIS FACTOR
C     APPEARS EVERY TIME THE TEMPERATURES ARE USED) AND STORED IN THE
C     SAME ARRAYS. AS WITH RHO(A), THE INDEX FOR THE LAYER WHOSE BOUN-
C     DARIES ARE A AND A+1 KM ABOVE THE EARTH'S SURFACE IS A.
C
C     THE PROGRAM ASSUMES THE LAYERING OF THE ATMOSPHERE IS IN 1 KM STRATA.
C
C     QRAT IS AN ARRAY STORING THE PRODUCT OF TWO RATIOS:
C                         THE VIBRATIONAL PARTITION FUNCTION AT TS (296 K) (QV) TO
C                         THE VIBRATIONAL PARTITION FUNCTION AT VBTMP (Z1)
C     AND                 THE ROTATIONAL  PARTITION FUNCTION AT TS (296 K) TO
C                         THE ROTATIONAL  PARTITION FUNCTION AT TRTMP
C     THE LATTER RATIO IS JUST A POWER OF THE RATIO OF TEMPERATURES,
C     TS/TRTMP, WHERE TRTMP IS THE ACTUAL TRANSLATIONAL TEMPERATURE.
C
C     ALCOR(A) IS READ IN AS THE TOTAL PRESSURE. AT STATEMENT 95 IT
C     BECOMES AN ARRAY STORING THE FACTOR BY WHICH THE LORENTZ LINEWIDTH
C     PARAMETER (GIVEN ON THE LINE FILE AT TS AND 1 ATMOSPHERE) IS MULTI-
C     PLIED TO CORRECT FOR PRESSURE AND TEMPERATURE AT VARIOUS ALTITUDES.
C
   90 QV = 1.0/(1.0 - EXP(-VIBQ/BST))**DEGV
      I = A - 1
      Y = 1.0 - TEXP
      DO 95 A = TANIN,I
      RHO(A)  = SQRT(RHO(A)*RHO(A+1))
      TRTMP(A) = 0.5*(TRTMP(A) + TRTMP(A+1))*BK
      VBTMP(A) = 0.5*(VBTMP(A) + VBTMP(A+1))*BK
      Z1 = 1.0/(1.0 - EXP(-VIBQ/(VBTMP(A))))**DEGV
      QRAT(A)  = (QV/Z1)*(BST/TRTMP(A))**PROT
   95 ALCOR(A) = ALCOR(A)*(BST/TRTMP(A))**Y
      WRITE(4,1)
C
C     ******************************************************************
C
C     CARD 3  AFGL LINE FILE CARDS---UNIT 3
C
C     THIS SECTION READ THE AFGL LINE FILE AND
C     SELECTS LINES OF INTEREST BASED ON TRANSITION STATES (UST,LST),
C     BRANCH (BR) AND LINE (NRQL) PARAMETERS SET IN CARD 1B. MOST OF
C     THE VARIABLES READ IN (VINIT, Z1, Z2...) ARE STORED IN ARRAYS
C     (V, STS, ALF...) PRIOR TO STATEMENT 131. THE VARIABLES THEM-
C     SELVES ARE LATER USED FOR MISCELLANEOUS OTHER PURPOSES.
C                        VINIT (V) = FREQUENCY OF VIBRATIONAL TRANSITION (CM-1)
C                        Z1  (STS) = LINE INTENSITY (CM-1/MOLECULE-CM2)
C                        Z2  (ALF) = LORENTZ HALF-WIDTH AT 296 K AND 1 ATMOSPHERE
C                                                       (CM-1/ATMOS)
```

```
      C                   Y    (EOP) = ENERGY OF THE LOWER STATE (CM-1)
      C                   US, LS     = UPPER AND LOWER STATE TRANSITIONS, RESPECTIVELY
      C                   BCH (BRNCH) = BRANCH (P, Q, OR R)
      C                   N  (RQL) = ROTATIONAL QUANTUM LINE
      C                   I = ISOTOPE CODE
      C
            WRITE(4,91) UST,LST
         91 FORMAT(5X,'AFGL LINE FILE OF INTEREST FOR TRANSITION ',
           1A5,' TO ',A5,/)
            WRITE(4,92)
         92 FORMAT(5X,'BRANCH',2X,'LINE',2X,'FREQ. (CM-1)',2X,
           1'LINE STRENGTH',2X,'LINEWIDTH',3X,'LOWER STATE ENERGY',/)
      C
      C     JMAX COUNTS THE TOTAL NUMBER OF LINES TO BE EXAMINED
      C
            JMAX = 0
      C*****
      C*****
        100 READ(3,110,END=135)VINIT,Z1,Z2,Y,US,LS,BCH,N,I
        110 FORMAT(F10.5,E10.3,F5.3,F10.3,3X,A5,3X,A5,14X,A1,I3,4X,I4)
      C
      C     PROGRAM EXAMINES AND RETURNS CORRECT TRANSITION STATE, LINE(S),
      C     AND BRANCH(ES) FOR THE GIVEN ISOTOPE. IF THE DOPPLER OPTION
      C     (NDP = 1) IS SELECTED, THE LORENTZ LINEWIDTHS ARE SET TO ZERO.
      C
            IF(VINIT.LT.VMIN)GO TO 100
            IF(VINIT.GT.VMAX)GO TO 100
            IF(ISO.NE.I)  GO TO 100
            IF(UST.NE.US) GO TO 100
            IF(LST.NE.LS) GO TO 100
            IF(BR.NE.'A'.AND.BR.NE.BCH) GO TO 100
            IF(NRQL.NE.N.AND.NRQL.NE.999)GO TO 100
      C
            JMAX = JMAX + 1
            V(JMAX) = VINIT
            STS(JMAX) = Z1
            ALF(JMAX) = Z2
            IF(NDP.EQ.1)ALF(JMAX) = 0.0
            EOP(JMAX) = Y
            BRNCH(JMAX) = BCH
            RQL(JMAX) = N
            WRITE(4,131) BCH,N,VINIT,Z1,Z2,Y
        131 FORMAT(7X,A1,5X,I3,4X,F10.5,4X,E10.3,6X,F5.3,7X,F10.3)
      C
            GO TO 100
        135 IF(JMAX.EQ.0)GO TO 998
            WRITE(4,1)
      C
      C     AT THIS POINT THE DATA HAVE ALL BEEN READ IN AND STORED IN THE
      C     APPROPRIATE ARRAYS. NOW DO SOME FURTHER INITIALIZATION AND THEN
      C     PROCEED WITH THE LOOPS WHICH PERFORM THE ACTUAL CALCULATIONS.
      C
      C     ******************************************************************
      C
      C     PRESET THE LINESHAPE ORDINATE. DVV IS THE "DISTANCE" IN CM-1
      C     FROM THE CENTER OF THE LINE IN QUESTION.
      C
```

```
      DO 138 L = 1,101
  138 DVV(L) = FLOAT(L-1)*1.0E-04
C
C     PRESET THE OPTICALLY THIN TEST ARRAY TO ZERO.
C
      DO 139 J = 1,JMAX
  139 JT(J) = 0
C
C     THE TOTAL NUMBER OF DIFFERENT LINE-OF-SIGHT PATHS TO BE CONSIDERED IN
C     ALL IS  (TANF-TANIN)/INTRVL + 1. THESE CASES ARE DONE IN GROUPS OF
C     FOUR (POSSIBLY LESS, IN THE CASE OF THE LAST GROUP) TO MAKE THE
C     PRINTED OUTPUT MANAGEABLE AND TO REDUCE THE SIZE OF CERTAIN
C     ARRAYS. THE LOOP DO 300 IS ENTERED ONCE FOR EACH GROUP. THE INTEGER
C     ARRAY  HTS  STORES THE TANGENT HEIGHTS (IN KM) WHICH PARAMETERIZE EACH
C     PATH. NREPS BECOMES THE NUMBER OF GROUPS WHICH MUST BE HANDLED. IMAX
C     BECOMES THE NUMBER OF CASES IN THE CURRENT GROUP.
C
      NREPS = (TANF-TANIN)/INTRVL+1
      NR  = MOD(NREPS,4)
      NREPS = NREPS/4
      IF(NR.GT.0) NREPS = NREPS+1
C
C*********************************************************************
C*
C*    LOOP TO SELECT GROUPS OF (4 OR LESS) TANGENT HEIGHTS. CALCULATE
C*    THESE CASES SIMULTANEOUSLY. WHEN THIS LOOP ENDS, EXECUTION
C*    TERMINATES.
C*
      DO 300 NR = 1,NREPS
      IMAX = 1
      DO 140 I = 1,4
      HTS(I) = TANIN + (4*(NR-1) + I - 1)*INTRVL
      IF(HTS(I).GT.TANF)GO TO 140
      IMAX = I
  140 CONTINUE
C*
C*    SUMRAD IS AN ARRAY THAT STORES THE SUM OF RADIANCES FROM ROTATIONAL
C*    TRANSITIONS FOR A GIVEN TANGENT HEIGHT. PRESET THIS ARRAY TO ZERO.
C*    ALSO CALCULATE THE ARRAY OF PATH LENGTHS ZZ, FOR EACH LAYER (A)
C*    AND EACH PATH (TANGENT HEIGHT) IN THIS GROUP. ACTUALLY, ZZ IS THE PRODUCT
C*    OF THE TOTAL NUMBER DENSITY AT THE ALTITUDE IN QUESTION AND THE  GEO-
C*    METRICAL PATH LENGTH IN THE SLAB. THE FACTOR 10**5 CONVERTS
C*    KM TO CM.
C*
      DO 145 I = 1,IMAX
      SUMRAD(I)= 0.0
      DO 145 N = 1,NLYR
      A  = NLYR + HTS(I) - N
      Z1 = SQRT(FLOAT(A - HTS(I))*(2.0*EARTHR + FLOAT(A + HTS(I))))
      Z2 = SQRT(FLOAT(A-HTS(I)+1)*(2.0*EARTHR + FLOAT(A+HTS(I)+1)))
  145 ZZ(A,I) = RHO(A)*(Z2 - Z1)*1.0E+05
      IF(IMAX.GT.1)WRITE(4,148)(HTS(I),HTS(I),I=1,IMAX)
      WRITE(4,2)
  148 FORMAT(//,5X,'RADIANCE (WATT/CM2*STR) AT VARIOUS TANGENT HEIGHTS',
     1//,5X,'LINE',3X,4(I3,' KM (THIN)',I5,' KM',5X))
C*
C* *******************************************************************
```

```
C**
C**   LOOP TO PERFORM CALCULATIONS ON ALL SELECTED ROTATIONAL LINES.
C**   QC CORRECTS FOR THE STIMULATED EMISSION AT TS (296 K).
C**   THE DOPPLER LINEWIDTH IS
C**       ALFD = SQRT(2*ALOG(2)*BOLTZ*TRTMP/(MOLWT*C*C))*VINIT
C**   WHERE TRTMP IS THE ACTUAL TRANSLATIONAL TEMPERATURE.
C**
      DO 200 J = 1,JMAX
      VINIT = V(J)
      QC = 1.0 - EXP(-VINIT/BST)
      DCPP = A2*SQRT(2.0*BOLTZ/(BK*WGT*C*C))*VINIT
C *
C *  ***********************************************************
C * *
C * * THE LOOP DO 150 CALCULATES PATH-INDEPENDENT QUANTITIES WHICH
C * * DEPEND ONLY ON ALTITUDE. ALTITUDES RUN FROM THE LOWEST REQUIRED FOR
C * * THE FIRST (LOWEST) LINE-OF-SIGHT PATH TO THE HIGHEST REQUIRED FOR THE
C * * LAST ONE IN THE CURRENT GROUP. NMAX IS THE NUMBER OF SUCH REQUIRED
C * * ALTITUDES.
C * *
C * * STS(J) GIVES THE LINE STRENGTH UNDER CONDITIONS OF LTE AT TEMPERATURE
C * * TS, WHICH WE REFER TO AS "STANDARD CONDITIONS". THE QUANTITY
C * * QRAT*EXP(Z1)  GIVES THE RATIO OF THE PROBABILITY OF FINDING THE
C * * MOLECULE IN THE LOWER RADIATING STATE AT ALTITUDE A (WHERE VBTMP
C * * AND TRTMP CHARACTERIZE THE DISTRIBUTION OF POPULATED STATES) TO THE
C * * PROBABILITY OF FINDING IT IN THE LOWER STATE UNDER STANDARD CONDITIONS.
C * * THE RATIO (1-GAM)/QC  CORRECTS FOR STIMULATED EMISSION AT ALTITUDE
C * * A  AND FOR STANDARD CONDITIONS. THE PRODUCT OF THESE THREE FACTORS
C * * GIVES THE LINE STRENGTH AT ALTITUDE A, S(A).  S(A)*F(NU) GIVES
C * * THE CONVENTIONAL ABSORPTION COEFFICIENT AT FREQUENCY NU.
C * *
      NMAX = HTS(IMAX) - HTS(1) + NLYR
      DO 150 N = 1,NMAX
      A = HTS(1) + N - 1
      GAM = EXP(-(VINIT-VIBE)/TRTMP(A))*EXP(-VIBE/VBTMP(A))
      GBB(A) = (GAM/(1.0-GAM))*2.0*C*VINIT**2
      Z1 = EDP(J)/BST - (EDP(J)-VIBL)/TRTMP(A) - VIBL/VBTMP(A)
      S(A) = STS(J)*QRAT(A)*(1.0 - GAM)*EXP(Z1)/QC
  150 DWID(A) = DOPP*SQRT(TRTMP(A))
      IF(JT(J).GE.1)GO TO 180
C * *
C *  ***************************************************************
C  *****************************************************************
C **
C **  THE LOOP DO 170 L = 101,1,-1 VARIES THE FREQUENCY BETWEEN THE  CENTER
C **  OF THE LINE AND THE WINGS. THE INTEGRATION OVER THE LINE-OF-SIGHT
C **  PATH (THE Z-INTEGRATION) IS THEREFORE COMPLETELY CARRIED OUT FOR ONE
C **  FREQUENCY FOR EACH TANGENT HEIGHT IN THE CURRENT GROUP BEFORE THE
C **  NEXT FREQUENCY IS CONSIDERED.
C **
C **  FOR SOME LINES, THERE MAY BE FREQUENCIES NEAR THE CENTER OF THE LINE
C **  WHERE THE LINE IS VERY THICK---THAT IS, FREQUENCIES FOR WHICH ALL
C **  RADIATION FROM SLAB (N-1) IS COMPLETELY ABSORBED IN SLAB (N), SO
C **  THAT AT THE END OF SLAB (N) THE RADIANCE IS ENTIRELY FROM THAT SLAB.
C **  FOR SUCH CASES, THE INTEGRATION THROUGH THE FIRST HALF OF THE LINE-
C **  OF-SIGHT PATH IS UNNECESSARY. BY SELECTING FREQUENCIES IN "BACKWARDS"
C **  ORDER---STARTING IN THE WING, WITH L = 101---WE CAN FLAG THE FRE-
```

```
      C **  QUENCIES NEAR THE LINE CENTER FOR WHICH THIS EXTRA WORK CAN BE
      C **  AVOIDED.
      C **
            DO 155 I = 1,4
        155 FLAG(I) = 0
            DO 170 L = 101,1,-1
      C **
      C **  THE  LOOP DO 160 CALCULATES, FOR ALL ALTITUDES REQUIRED, THE VALUES
      C **  OF THE VOIGT PROFILE AT THE "DISTANCE" FROM THE CENTER OF THE LINE
      C **  INDEXED BY THE CURRENT VALUE OF L---THAT IS, DVV(L) CM-1 FROM THE
      C **  CENTER.
      C **
            DO 160 N = 1,NMAX
            A = HIS(1) + N - 1
            ALFD = DWID(A)
            Y = DVV(L)/ALFD
            RAT = A2*(ALF(J)*ALCOR(A))/ALFD
        160 VGT(A) = WNERF(Y,RAT)/ALFD
      C **
      C ** ******************************************************************
      C ***
      C *** THE LOOP DO 170 I = 1,IMAX VARIES THE TANGENT HEIGHTS. THE PROFILE ARRAY,
      C *** NWZ, IS ALSO INITIALIZED, AND THE FLAG IS CHECKED AND POSSIBLY RESET.
      C ***
            DO 170 I = 1,IMAX
            NWZ(L,I) = 0.0
            IF(FLAG(I).EQ.1)GO TO 169
            A = HIS(I)
            Z1 = S(A)*ZZ(A,I)*VGT(A)
            IF(Z1.GE.35.)FLAG(I) = 1
      C ***
      C ***      START THE Z-INTEGRATION ALONG THE LINE-OF-SIGHT AT THE FAR
      C ***      HORIZON. THE LOOP DO 165 CARRIES THE CALCULATION TO THE TANGENT
      C ***      HEIGHT POINT. IN THIS LOOP, AND IN THE NEXT ONE, Z1 BECOMES THE
      C ***      OPTICAL DEPTH OF THE CURRENT SLAB AT THE FREQUENCY IN QUESTION.
      C ***
                 DO 165 N = 1,NLYR
                 A = NLYR + HIS(I) - N
                 Z1 = S(A)*ZZ(A,I)*VGT(A)
                 Z2 = 0.0
                 IF(Z1.LT.35.)Z2 = EXP(-Z1)
        165      NWZ(L,I) = NWZ(L,I)*Z2 + (1.0 - Z2)*GBB(A)
      C ***
      C ***      COMPLETE THE Z-INTEGRATION BY CARRYING IT FROM THE TANGENT HEIGHT
      C ***      POINT THROUGH NYLR SLABS TO THE OBSERVATION POINT.
      C ***
        169      DO 170 N = 1,NLYR
                 A = HIS(I) + N - 1
                 Z1 = S(A)*ZZ(A,I)*VGT(A)
                 Z2 = 0.0
                 IF(Z1.LT.35.)Z2 = EXP(-Z1)
        170 NWZ(L,I) = NWZ(L,I)*Z2 + (1.0 - Z2)*GBB(A)
      C ***
      C *** END THE LOOP (INDEX L) THAT VARIES THE FREQUENCY. THE LINE PROFILE, NWZ,
      C *** HAS BEEN FOUND AS A FUNCTION OF FREQUENCY (INDEXED BY L) FOR EACH TAN-
      C *** GENT HEIGHT (INDEXED BY I) IN THE CURRENT GROUP.
      C ***
```

```
C * ****************************************************************
C *
C *  ***************************************************************
C * *
C * * THE LOOP DO 190 RUNS THROUGH THE TANGENT HEIGHTS IN THE CURRENT GROUP.
C * * INTEGRATE OVER THE OPTICAL LINE, USING SIMPSON'S RULE WITH 50 PANELS
C * * Z2 IS THE SUM OF OF EVEN TERMS (THE ENDS OF EACH PANEL); Z1, OF ODD TERMS
C * * THE RESULT, RAD(I), HAS UNITS OF WATT/CM2-STR
C * *
  180 DO 190 I = 1,IMAX
      THINR(I) = 0.0
      DO 185 N = 1,NLYR
      A = NLYR + HTS(I) - N
  185 THINR(I) = THINR(I) + GBB(A)*S(A)*ZZ(A,I)
      THINR(I) = 2.0*THINR(I)*H*C*VINIT
      RAD(I) = THINR(I)
      IF(JT(J).GE.1)GO TO 190
      Z2 = 0.0
      Z1 = 0.0
      DO 188 L = 2,98,2
      Z2 = Z2 + NVZ(L,I)
      Z1 = Z1 + NVZ(L+1,I)
  188 CONTINUE
      Z2 = Z2 + NVZ(100,I)
      RAD(I) = (NVZ(1,I) + 4.0*Z2 + 2.0*Z1 + NVZ(101,I))/3.0
      RAD(I) = RAD(I)*2.0E-04*H*C*VINIT
      IF((ABS(THINR(I)-RAD(I))).LT.(RAD(I)*.05)) JT(J) = I
  190 SUMRAD(I) = SUMRAD(I) + RAD(I)
C * *
C * * END THE LAST LOOP (INDEX I) THAT VARIES THE TANGENT HEIGHT
C * *
C *  ***************************************************************
C *
C *   IF ONLY ONE LINE IS CALCULATED, PRINT OUT THE LINESHAPE
C *
      N = JT(J)
      IF(N.EQ.0)N = IMAX
      IF(JMAX.NE.1)GO TO 195
      IF(N.EQ.5)GO TO 194
      WRITE(4,191)BR,NRQL,(HTS(I),I=1,IMAX)
  191 FORMAT(///,' RADIANCE (PHOTONS/CM2*STR*SEC*CM-1) FOR LINE  ',
     1A1,I3,' VS FREQUENCY (CM-1) AT VARIOUS TANGENT HEIGHTS',//,
     27X,'FREQ',2X,4(2X,I9,' KM'))
  192 FORMAT(F13.4,2X,4E14.5)
      WRITE(4,2)
      DO 193 L = 1,101
      IF(NVZ(L,N).EQ.0.0)GO TO 194
      Z1 = VINIT + DVV(L)
  193 WRITE(4,192)Z1,(NVZ(L,I),I=1,N)
  194 WRITE(4,1)
      WRITE(4,140)(HTS(I),HTS(I),I=1,IMAX)
      WRITE(4,2)
C *
C *   PRINT OUT THE RADIANCES
C *
  195 WRITE(4,196)BRNCH(J),RQL(J),(THINR(I),I=1,IMAX)
      IF(N.LT.5)WRITE(4,197)(RAD(I),I=1,N)
```

```
  196 FORMAT(5X,A1,I4,4(2X,E12.5,12X))
  197 FORMAT(1H+,9X,A(14X,E12.5))
      IF(JT(J).GT.0)JT(J) = 5
C**
  200 CONTINUE
C**
C**   END THE LOOP (INDEX J) THAT CHOOSES DIFFERENT LINES
C**
C* ************************************************************************
C*
      WRITE(4,1)
      IF(JMAX.GT.1)WRITE(4,201)JMAX,(SUMEAC(I),I=1,IMAX)
  201 FORMAT('    TOTAL FOR',I4,' LINES =',4(E12.5,14X))
      WRITE(4,1)
  300 CONTINUE
C*
C*    END THE LOOP (INDEX NR) SELECTING DIFFERENT GROUPS OF LINE-OF-SIGHT PATHS
C*
C*************************************************************************
C
  998 IF(JMAX.EQ.0)WRITE(4,990)
  990 FORMAT(////,' ***** NO LINES FOUND ******',////)
      CLOSE (UNIT=1)
      CLOSE (UNIT=2)
      CLOSE (UNIT=3)
      CLOSE (UNIT=4)
      END
```

```
      FUNCTION VWERF (XX,A)
C
C     THE METHOD IS DUE TO RYBICKI. THE FORTRAN LISTING WAS
C     PUBLISHED AS AN APPENDIX TO E. H. AVRETT AND R. LOESER,
C     "FORMATION OF LINE AND CONTINUOUS SPECTRA," SPECIAL REPORT 303,
C     SMITHSONIAN ASTROPHYSICAL OBSERVATORY, CAMBRIDGE, MASS. (1970)
C
C     THE METHOD OF CALCULATION IS DESCRIBED BY B. H. ARMSTRONG
C     AND R. W. NICHOLLS, "EMISSION, ABSORPTION AND TRANSFER OF
C     RADIATION IN HEATED ATMOSPHERES," PERGAMON PRESS,NEW YORK,
C     (1972) - PP. 235-237.
      COMPLEX Z
      DIMENSION C(131)
      DATA NTRY,NMAX,RH,PI,C2,Q2 /1,15,3.0,3.1415926535898,
     1 5.64189583547756E-01,8.97935610625833E-02/
      IF (NTRY .EQ. 1)  GO TO 170
  110 CONTINUE
      X = RTLN2*XX
      IF (A .EQ. 0.0)  GO TO 160
      IF ((X + A) .GT. 25.0)  GO TO 190
C     DO COMPUTATION FOR GENERAL CASE
      A1 = RH*A
      A2 = A*A
      IF (A .LT. 0.1)  GO TO 120
      Z = CEXP(CMPLX(-Q1*A,Q1*X))
      VWERF = 0.0
      GO TO 130
  120 CONTINUE
      Z = CCOS(CMPLX(Q1*X,Q1*A))
      VWERF = C2*EXP(A2 - X*X)*COS(2.0*A*X)
  130 CONTINUE
      B1 = (1.0 - REAL(Z))*A*0.5*RH
      B2 = -AIMAG(Z)
      S = -0.5*(FLOAT(NP1) + RH*X)
      T = S*S + 0.25*RHSQ*A2
      DO 150 N = 1, NPNP1
      T = T + S + 0.25
      S = S + 0.5
      B1 = A1 - B1
      B2 = -B2
      IF (T .GT. 2.5E-12)  GO TO 140
      VWERF = VWERF - C(N)*A/RH
      GO TO 150
  140 CONTINUE
      VWERF = VWERF + C(N)*(B2*S + B1)/T
  150 CONTINUE
  155 CONTINUE
      VWERF = VWERF*RTLN2
      RETURN
  160 CONTINUE
      VWERF = RTLN2*Q2*EXP(-X*X)
      RETURN
  170 CONTINUE
      NTRY = 0
      NP1 = NMAX + 1
      NPNP1 = NMAX + NP1
      RHSQ = RH*RH
```

```
            K = -NP1
           DO 180 N = 1, NPNP1
            K = K + 1
            C(N) = C3*EXP(-FLOAT(K*K)/RESC)
       180  CONTINUE
            C1 = RH*EI
            RTLN2 = SQRT(ALOG(2.0))
            GO TO 110
       190  CONTINUE
      C
      C    USE ASYMPTOTIC EXPANSION FOR COMPLEX ERROR FUNCTION
      C    FOR LARGE X AND A.
      C
            AN = 2.5
            DENR = A
            DENI = -X
           DO 200 I = 1, 5
            DEN = AN/(DENR*DENR + DENI*DENI)
            DENR = DEN*DENR + A
            DENI = -DENI*DEN - X
            AN = AN - 0.5
       200  CONTINUE
            DEN = Q2/(DENR*DENR + DENI*DENI)
            VHERE = RTLN2*Q2*DEN*DENR
            RETURN
           END
```

```
      SUBROUTINE MOLEC(MOL,ISO,MOLWT,DEGV,PROT,TEXP)
C
C     THIS SUBROUTINE, GIVEN THE MOLECULE CODE (MOL) AND THE ISOTOPE CODE
C     (ISO), RETURNS PARAMETERS WHICH ARE UNIQUELY ASSOCIATED WITH THE
C     MOLECULE IN QUESTION:  MOLWT, THE MOLECULAR WEIGHT
C                            DEGV,  THE DEGENERACY OF THE VIBRATIONAL MANIFOLD
C                            PROT,  THE EXPONENT OF TEMPERATURE IN THE
C                                   ROTATIONAL PARTITION FUNCTION
C                            TEXP,  THE EXPONENT OF TEMPERATURE IN
C                                   THE LORENTZ-LINEWIDTH CORRECTION
C
C     FOR CH4 THE CORRECT PARTITION FUNCTION RESULTS (TO WITHIN
C     1% UP TO 800 K) IF A SINGLE LEVEL AT 1370 CM-1 WITH A DE-
C     GENERACY OF 5 IS CHOSEN.
C
C     DEGV IS 2  FOR LINEAR TRIATOMIC MOLECULES, 1 OTHERWISE (XC CH4)
C     PROT IS 1  FOR ALL LINEAR MOLECULES, 1.5 OTHERWISE
C     TEXP IS .25 FOR CO2, .5 OTHERWISE
C
      INTEGER DEGV
      CHARACTER*5 MOLCOD(7),MOL
      DIMENSION MOLWGT(7),MOLISO(7)
      DATA (MOLCOD(I),I=1,7)/'H2O','CO2','O3 ','N2O','CO ','CH4','O2 '/
      DATA (MOLISO(I),I=1,7)/161,626,666,446,26,211,66/
      DATA (MOLWGT(I),I=1,7)/18,44,48,44,28,16,32/
C
      MOLWT = 0
      IC = 0
      PROT = 1.5
      DEGV = 1
      TEXP = 0.5
      DO 100 I = 1,7
  100 IF(MOLCOD(I).EQ.MOL)IC = I
      IF(IC.EQ.0)RETURN
      IF(IC.EQ.1.OR.IC.EQ.3)GO TO 120
      IF(IC.EQ.2)TEXP = .25
      IF(IC.NE.7)PROT = 1.0
      IF(IC.LT.5)DEGV = 2
      IF(IC.EQ.7)DEGV = 5
  120 MDIFF = ISO - MOLISO(IC)
      IF(MDIFF)130,140,150
  130 ISO = MOLISO(IC)
  140 MOLWT = MOLWGT(IC)
      RETURN
C
  150 M1 = MDIFF/100
      M2 = (MDIFF - 100*M1)/10
      M3 = (MDIFF - 100*M1 - 10*M2)
      MOLWT = MOLWGT(IC) + M1 + M2 + M3
      IF(M1.GT.2.OR.M2.GT.2.OR.M3.GT.2)MOLWT = 0
      RETURN
      END
```

Appendix B

Example of Program Output for a Single Line of the 01101-00001 Band of CO_2. The Voigt Lineshape is Used. The Spectral Lineshape and the Integrated Radiance is Calculated for Four Tangent Heights

MOL = CO2
ISO = ISOTOPE CODE = 626
VIBE = VIBRATIONAL ENERGY (CM-1) OF THE TRANSITION = 667.380
VIBL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE = 0.000
VIBQ = VIBRATIONAL QUANTUM (CM-1) (FOR PARTITION FUNCTION) = 667.380

MOLWT = 44
DEGV = 2
PROT = 1.0
TEXP = .25

PROGRAM WILL SEARCH THE LINE FILE BETWEEN 0 AND 50000 CM-1 FOR LINES OF CO2
ISOTOPE = 626
BAND = 01101 - 00001
BRANCH = R
LINE # = 2
VOIGT = LINESHAPE OPTION SELECTED

INITIAL TANGENT HEIGHT (KMS) = 70
FINAL TANGENT HEIGHT (KMS) = 85
EXAMINATION INTERVAL (KMS) = 5

ATMOSPHERE---" CO2,NIGHT, 70-190 KM; T, P = US STD76; VIB TEMP = CO2,NIGHT, 70-190 K 05/12/83 "

ALT (KM)	TR TEMP (K)	VB TEMP (K)	TOT PRESS (ATMOS)	CO2 DENSITY (CM-3)
70	219.590	211.760	.515260E-04	.542350E+12
71	216.925	208.526	.441680E-04	.470690E+12
72	214.260	205.223	.378610E-04	.408490E+12
73	212.305	201.843	.323500E-04	.352280E+12
74	210.350	198.393	.276420E-04	.303800E+12
75	208.390	194.869	.235520E-04	.261250E+12
76	206.430	191.464	.200670E-04	.224730E+12
77	204.475	188.136	.171620E-04	.192750E+12
78	202.520	184.602	.157210E-04	.165320E+12
79	200.565	181.194	.122790E-04	.141380E+12
80	198.610	177.799	.103870E-04	.123910E+12
81	196.655	174.452	.876890E-05	.103090E+12
82	194.700	171.220	.740280E-05	.879010E+11
83	192.745	168.144	.622880E-05	.747140E+11
84	190.780	165.253	.524100E-05	.635050E+11
85	188.825	162.555	.439470E-05	.538020E+11
86	186.870	160.817	.368500E-05	.455820E+11
87	186.870	159.329	.308520E-05	.381540E+11
88	186.870	158.097	.258310E-05	.319360E+11
89	186.870	157.124	.216340E-05	.267340E+11
90	186.870	156.408	.181190E-05	.223800E+11
91	187.115	156.054	.151810E-05	.187170E+11
92	187.360	155.924	.127190E-05	.156530E+11
93	187.845	156.007	.106620E-05	.130850E+11
94	188.330	156.292	.893750E-06	.109380E+11
95	188.820	156.809	.749970E-06	.915240E+10
96	189.310	157.279	.629320E-06	.765830E+10
97	190.755	157.845	.529000E-06	.638850E+10

98	192.200	158.590	.444680E-06	.532920E+10
99	193.640	159.235	.374820E-06	.445800E+10
100	195.080	160.514	.315930E-06	.372930E+10
101	197.640	161.965	.268630E-06	.311360E+10
102	200.200	163.340	.228410E-06	.259960E+10
103	202.755	164.816	.195080E-06	.218060E+10
104	205.310	166.330	.166610E-06	.182910E+10
105	209.415	168.365	.143110E-06	.153170E+10
106	213.520	170.947	.122910E-06	.128260E+10
107	218.750	173.256	.106320E-06	.107670E+10
108	223.980	175.584	.919700E-07	.903870E+09
109	231.990	177.826	.803110E-07	.703320E+09
110	240.000	180.738	.701130E-07	.547270E+09
111	252.000	184.252	.615970E-07	.427590E+09
112	264.000	187.580	.548210E-07	.334090E+09
113	276.000	190.715	.490530E-07	.266740E+09
114	288.000	193.654	.438920E-07	.212960E+09
115	300.000	196.865	.396610E-07	.173140E+09
116	312.000	200.369	.358370E-07	.140760E+09
117	324.000	203.701	.326520E-07	.116220E+09
118	336.000	206.862	.297500E-07	.959550E+08
119	348.000	209.852	.272990E-07	.802870E+08
120	360.000	212.379	.250500E-07	.671780E+08
121	371.445	214.402	.231270E-07	.564350E+08
122	382.890	216.214	.213520E-07	.482540E+08
123	394.335	217.924	.198160E-07	.412950E+08
124	405.780	219.243	.183910E-07	.353400E+08
125	416.710	220.579	.171450E-07	.305380E+08
126	427.640	221.845	.159830E-07	.263880E+08
127	438.045	222.952	.149570E-07	.229540E+08
128	448.450	223.909	.139970E-07	.200360E+08
129	458.860	224.727	.131430E-07	.175700E+08
130	469.270	225.533	.123410E-07	.154070E+08
131	478.305	226.346	.116230E-07	.136230E+08
132	487.340	227.053	.109470E-07	.120450E+08
133	496.375	227.662	.103370E-07	.106990E+08
134	505.410	228.177	.976140E-08	.953280E+07
135	514.450	228.641	.923970E-08	.847630E+07
136	523.490	229.068	.874590E-08	.756070E+07
137	532.525	229.427	.829620E-08	.677060E+07
138	541.560	229.723	.786960E-08	.606300E+07
139	551.595	229.959	.747350E-08	.544940E+07
140	559.630	230.139	.710870E-08	.489790E+07
141	567.105	230.274	.676920E-08	.442830E+07
142	574.580	230.368	.644400E-08	.400380E+07
143	582.055	230.423	.614530E-08	.362960E+07
144	589.530	230.441	.586040E-08	.329630E+07
145	597.010	230.426	.559710E-08	.299420E+07
146	604.490	230.385	.534540E-08	.271750E+07
147	611.965	230.319	.511210E-08	.247560E+07
148	619.440	230.230	.488900E-08	.225520E+07
149	626.915	230.119	.468150E-08	.205910E+07
150	634.390	229.979	.448280E-08	.188000E+07
151	640.580	229.814	.430630E-08	.172920E+07
152	646.770	229.636	.413670E-08	.159050E+07
153	652.960	229.445	.397380E-08	.146290E+07
154	659.150	229.242	.381730E-08	.134560E+07
155	665.340	228.993	.366700E-08	.123760E+07
156	671.530	228.700	.352260E-08	.113840E+07
157	677.720	228.401	.338390E-08	.104710E+07
158	683.910	228.098	.325070E-08	.963070E+06
159	690.100	227.790	.312270E-08	.885820E+06
160	696.290	227.460	.299970E-08	.814770E+06
161	701.418	227.108	.289370E-08	.755630E+06
162	706.546	226.757	.279140E-08	.700780E+06
163	711.674	226.406	.269280E-08	.649920E+06

164	716.802	226.055	.259760E-08	.602740E+06
165	721.930	225.705	.250580E-08	.558590E+06
166	727.058	225.356	.241730E-08	.518420E+06
167	732.186	225.008	.233190E-08	.480790E+06
168	737.314	224.662	.224950E-08	.445890E+06
169	742.442	224.318	.217000E-08	.413530E+06
170	747.570	223.955	.209330E-08	.383510E+06
171	751.633	223.575	.202570E-08	.357850E+06
172	755.696	223.199	.196020E-08	.333910E+06
173	759.759	222.827	.189690E-08	.311570E+06
174	763.822	222.460	.183560E-08	.290720E+06
175	767.885	222.096	.177620E-08	.271270E+06
176	771.948	221.737	.171880E-08	.253120E+06
177	776.011	221.382	.166330E-08	.236190E+06
178	780.074	221.032	.160950E-08	.220380E+06
179	784.137	220.687	.155750E-08	.205640E+06
180	788.200	220.331	.150720E-08	.191880E+06
181	791.766	219.965	.1462[illegible]E-08	.179780E+06
182	795.332	219.605	.141820E-08	.168440E+06
183	798.898	219.251	.137570E-08	.157810E+06
184	802.464	218.901	.133450E-08	.147850E+06
185	806.030	218.557	.129450E-08	.138530E+06
186	809.596	218.219	.125570E-08	.129790E+06
187	813.162	217.885	.121810E-08	.121600E+06
188	816.728	217.558	.118160E-08	.113930E+06
189	820.234	217.235	.114610E-08	.106740E+06
190	823.860	216.909	.111180E-08	.100010E+06

AFGL LINE FILE OF INTEREST FOR TRANSITION 01101 TO 30001

BRANCH	LINE	FREQ. (CM-1)	LINE STRENGTH	LINEWIDTH	LOWER STATE ENERGY
R	2	669.72630	.597E-19	.077	2.341

RADIANCE (PHOTONS/CM2*STR*SEC*CM-1) FOR LINE R 2 VS FREQUENCY (CM-1) AT VARIOUS TANGENT HEIGHTS

FREQ	70 KM	75 KM	80 KM	85 KM
669.7263	.91440E+14	.94348E+14	.96836E+14	.99414E+14
669.7264	.90971E+14	.93855E+14	.96327E+14	.98892E+14
669.7265	.89580E+14	.92391E+14	.94816E+14	.97342E+14
669.7266	.87319E+14	.90010E+14	.92353E+14	.94813E+14
669.7267	.84284E+14	.86807E+14	.89033E+14	.91393E+14
669.7268	.80623E+14	.82931E+14	.85002E+14	.87223E+14
669.7269	.76561E+14	.78605E+14	.80472E+14	.82507E+14
669.7270	.72435E+14	.74150E+14	.75746E+14	.77526E+14
669.7271	.68774E+14	.70056E+14	.71265E+14	.72665E+14
669.7272	.66455E+14	.67100E+14	.67696E+14	.68464E+14
669.7273	.66978E+14	.66572E+14	.66066E+14	.65630E+14
669.7274	.72700E+14	.70500E+14	.67882E+14	.64742E+14
669.7275	.86338E+14	.81259E+14	.74627E+14	.64625E+14
669.7276	.10961E+15	.10007E+15	.84943E+14	.58821E+14
669.7277	.14193E+15	.12446E+15	.87978E+14	.43047E+14
669.7278	.17935E+15	.14212E+15	.71123E+14	.25134E+14
669.7279	.21241E+15	.13135E+15	.44816E+14	.12570E+14
669.7280	.22397E+15	.97991E+14	.24608E+14	.58502E+13
669.7281	.20829E+15	.66941E+14	.13410E+14	.27559E+13
669.7282	.18250E+15	.47346E+14	.80768E+13	.14356E+13

669.7283	.16007E+15	.36511E+14	.56365E+13	.88276E+12
669.7284	.14336E+15	.30407E+14	.44562E+13	.64023E+12
669.7285	.13076E+15	.26572E+14	.37996E+13	.51992E+12
669.7286	.12063E+15	.23825E+14	.33657E+13	.44887E+12
669.7287	.11200E+15	.21651E+14	.30368E+13	.39948E+12
669.7288	.10438E+15	.19825E+14	.27669E+13	.36119E+12
669.7289	.97532E+14	.18246E+14	.25365E+13	.32963E+12
669.7290	.91319E+14	.16859E+14	.23359E+13	.30274E+12
669.7291	.85657E+14	.15628E+14	.21593E+13	.27939E+12
669.7292	.80481E+14	.14531E+14	.20027E+13	.25885E+12
669.7293	.75739E+14	.13547E+14	.18630E+13	.24063E+12
669.7294	.71387E+14	.12662E+14	.17377E+13	.22436E+12
669.7295	.67385E+14	.11861E+14	.16250E+13	.20973E+12
669.7296	.63698E+14	.11135E+14	.15231E+13	.19651E+12
669.7297	.60296E+14	.10475E+14	.14306E+13	.18454E+12
669.7298	.57151E+14	.98715E+13	.13465E+13	.17365E+12
669.7299	.54238E+14	.93196E+13	.12697E+13	.16371E+12
669.7300	.51537E+14	.88131E+13	.11993E+13	.15462E+12
669.7301	.49027E+14	.83470E+13	.11347E+13	.14627E+12
669.7302	.46692E+14	.79172E+13	.10752E+13	.13859E+12
669.7303	.44516E+14	.75200E+13	.10205E+13	.13151E+12
669.7304	.42486E+14	.71521E+13	.96977E+12	.12496E+12
669.7305	.40589E+14	.68108E+13	.92280E+12	.11890E+12
669.7306	.38813E+14	.64934E+13	.87919E+12	.11327E+12
669.7307	.37150E+14	.61978E+13	.83963E+12	.10803E+12
669.7308	.35589E+14	.59220E+13	.80083E+12	.10315E+12
669.7309	.34124E+14	.56643E+13	.76556E+12	.98602E+11
669.7310	.32745E+14	.54232E+13	.73259E+12	.94348E+11
669.7311	.31447E+14	.51972E+13	.70171E+12	.90361E+11
669.7312	.30224E+14	.49851E+13	.67276E+12	.86632E+11
669.7313	.29070E+14	.47857E+13	.64558E+12	.83127E+11
669.7314	.27980E+14	.45981E+13	.62003E+12	.79831E+11
669.7315	.26949E+14	.44214E+13	.59597E+12	.76730E+11
669.7316	.25974E+14	.42547E+13	.57329E+12	.73806E+11
669.7317	.25050E+14	.40973E+13	.55190E+12	.71048E+11
669.7318	.24174E+14	.39485E+13	.53168E+12	.68442E+11
669.7319	.23342E+14	.38077E+13	.51256E+12	.65978E+11
669.7320	.22553E+14	.36742E+13	.49446E+12	.63641E+11
669.7321	.21802E+14	.35477E+13	.47731E+12	.61435E+11
669.7322	.21088E+14	.34277E+13	.46103E+12	.59338E+11
669.7323	.20408E+14	.33136E+13	.44558E+12	.57348E+11
669.7324	.19761E+14	.32052E+13	.43090E+12	.55456E+11
669.7325	.19143E+14	.31020E+13	.41693E+12	.53657E+11
669.7326	.18553E+14	.30037E+13	.40364E+12	.51945E+11
669.7327	.17991E+14	.29100E+13	.39097E+12	.50312E+11
669.7328	.17453E+14	.28207E+13	.37890E+12	.48756E+11
669.7329	.16939E+14	.27354E+13	.36737E+12	.47273E+11
669.7330	.16447E+14	.26539E+13	.35637E+12	.45856E+11
669.7331	.15976E+14	.25760E+13	.34585E+12	.44502E+11
669.7332	.15525E+14	.25016E+13	.33580E+12	.43207E+11
669.7333	.15092E+14	.24302E+13	.32618E+12	.41968E+11
669.7334	.14678E+14	.23620E+13	.31696E+12	.40782E+11
669.7335	.14280E+14	.22965E+13	.30814E+12	.39646E+11
669.7336	.13898E+14	.22337E+13	.29968E+12	.38556E+11
669.7337	.13530E+14	.21735E+13	.29156E+12	.37512E+11
669.7338	.13178E+14	.21157E+13	.28377E+12	.36501E+11
669.7339	.12839E+14	.20602E+13	.27629E+12	.35545E+11
669.7340	.12512E+14	.20068E+13	.26910E+12	.34620E+11
669.7341	.12198E+14	.19555E+13	.26219E+12	.33730E+11
669.7342	.11896E+14	.19061E+13	.25554E+12	.32874E+11
669.7343	.11604E+14	.18586E+13	.24914E+12	.32051E+11
669.7344	.11323E+14	.18128E+13	.24299E+12	.31251E+11
669.7345	.11052E+14	.17687E+13	.23705E+12	.30495E+11
669.7346	.10791E+14	.17262E+13	.23133E+12	.29759E+11
669.7347	.10539E+14	.16852E+13	.22582E+12	.29049E+11
669.7348	.10295E+14	.16457E+13	.22050E+12	.28365E+11

669.7349	.10060E+14	.16075E+13	.21537E+12	.27704E+11
669.7350	.98328E+13	.15706E+13	.21142E+12	.27063E+11
669.7351	.96132E+13	.15350E+13	.20563E+12	.26451E+11
669.7352	.94008E+13	.15006E+13	.20101E+12	.25856E+11
669.7353	.91953E+13	.14674E+13	.19654E+12	.25281E+11
669.7354	.89965E+13	.14352E+13	.19222E+12	.24725E+11
669.7355	.88040E+13	.14041E+13	.18804E+12	.24187E+11
669.7356	.86176E+13	.13740E+13	.18400E+12	.23666E+11
669.7357	.84370E+13	.13448E+13	.18008E+12	.23162E+11
669.7358	.82621E+13	.13166E+13	.17629E+12	.22675E+11
669.7359	.80925E+13	.12892E+13	.17262E+12	.22202E+11
669.7360	.79280E+13	.12627E+13	.16906E+12	.21744E+11
669.7361	.77686E+13	.12370E+13	.16561E+12	.21300E+11
669.7362	.76138E+13	.12121E+13	.16226E+12	.20870E+11
669.7363	.74636E+13	.11879E+13	.15902E+12	.20452E+11

RADIANCE (WATT/CM2*STR) AT VARIOUS TANGENT HEIGHTS

LINE	70 KM (THIN)	70 KM	75 KM (THIN)	75 KM	80 KM (THIN)	80 KM	85 KM (THIN)	85 KM
R 2	.77307E-05	.13544E-07	.25310E-05	.59142E-08	.75667E-06	.37663E-08	.23202E-06	.31254E-08

Appendix C

Example of Program Output for All Lines of the 01101-00001 Band of CO_2. The Doppler Lineshape is Used. The Integrated Radiance is Printed Out for a Single Tangent Height

MOL = CO2
ISO = ISOTOPE CODE = 6[illegible]6
VIBE = VIBRATIONAL ENERGY (CM-1) OF THE TRANSITION = 667.30[illegible]
VIBL = VIBRATIONAL ENERGY (CM-1) OF THE LOWER STATE = [illegible].000
VIBQ = VIBRATIONAL QUANTUM (CM-1) (FOR PARTITION FUNCTION) = 667.38[illegible]

MOLWT = 44
DEGV = [illegible]
PROT = 1.[illegible]
TEXP = .[illegible]5

PROGRAM WILL SEARCH TH[illegible] LINE FILE BETWEEN [illegible] AND 5[illegible]00[illegible] CM-1 FOR LINES OF CO[illegible]
ISOTOPE = 626
BAND = [illegible]1 - [illegible] 1
BRANCH = A (ALL)
LINE # = ** (ALL)
DOPPLER = LINESHAPE OP[illegible]ION SELECTED

INITIAL TANGENT HEIGHT (KMS) = 70
FINAL TANGENT HEIGHT (KMS) = 70
EXAMINATION INTERVAL (KMS) = 5

ATMOSPHERE---" CO2,NIGH., 70-19[illegible] KM; T, P = US STD76; VIB TEMP = CO2,NIGH[illegible], [illegible]-190 K [illegible]/12/[illegible]

ALT (KM)	TR TEMP (K)	VB TEMP (K)	TOT PRESS (ATMOS)	CO2 DENSITY (CM-3)
7	[illegible]9.595	21[illegible].760	.5152[illegible]0E-04	.54235[illegible]E+12
7[illegible]	216.925	20[illegible].526	.441680E-04	.47569[illegible]E+12
7[illegible]	[illegible]14.260	20[illegible].223	.37[illegible]610E-04	.40049[illegible]E+12
7[illegible]	212.305	20[illegible].[illegible]3	.3235[illegible]0E-04	.35228 E+12
7[illegible]	210.350	19[illegible].[illegible]33	.276[illegible]0E-04	.30380[illegible]E+12
75	2[illegible].390	19[illegible].[illegible]69	.235520E-04	.26129[illegible]E+12
76	[illegible]6.43[illegible]	19[illegible].[illegible]64	.20[illegible]70E-04	.22473 E+12
77	2[illegible]4.475	18[illegible].[illegible]36	.177620E-04	.19275[illegible]E+12
78	2[illegible]2.520	18[illegible].6[illegible]2	.157210E-04	.16532[illegible]E+12
79	[illegible]0.565	18[illegible].1[illegible]	.12779[illegible]E-04	.14138 E+12
8[illegible]	198.610	17[illegible].799	.103[illegible]70E-04	.12091[illegible]E+12
[illegible]	[illegible]6.655	17[illegible].45[illegible]	.[illegible]76[illegible]E-05	.10[illegible]9[illegible]E+12
8[illegible]	[illegible]94.70[illegible]	17[illegible].22[illegible]	.74[illegible]280E-05	.87901[illegible]E+11
8[illegible]	192.740	16[illegible].[illegible]44	.62[illegible]8[illegible]0E-05	.74714[illegible]E+11
84	190.780	165.253	.524100E-05	.63505[illegible]E+11
8[illegible]	1[illegible]8.825	16[illegible].555	.439[illegible]7[illegible]E-05	.53802 E+11
[illegible]	1[illegible]6.[illegible]70	16[illegible].[illegible]7	.368[illegible]00E-05	.45582[illegible]E+11
87	186.870	159.329	.309520E-05	.38154[illegible]E+11
88	186.870	15[illegible].[illegible]97	.258310E-05	.319360E+11
89	1[illegible]6.870	157.124	.216340E-05	.26734[illegible]E+11
9[illegible]	[illegible]6.87[illegible]	15[illegible].4[illegible]8	.1[illegible]1190E-05	.22380[illegible]E+11
9[illegible]	187.115	15[illegible].[illegible]54	.151[illegible]10E-05	.18717[illegible]E+11
92	187.360	155.924	.127190E-05	.15653[illegible]E+11
93	187.845	15[illegible].[illegible]7	.106620E-05	.13085[illegible]E+11
94	188.330	15[illegible].292	.893750E-06	.10938[illegible]E+11
95	1[illegible].[illegible]2[illegible]	15[illegible].8[illegible]9	.749970E-06	.91524[illegible]E+10
96	189.31[illegible]	157.279	.629320E-06	.76583[illegible]E+10

97	190.755	157.645	.524600E-06	.63885 E+10
98	192.203	158.503	.444680E-06	.53292 E+10
99	193.640	159.035	.374520E-06	.44580 E+10
100	195.080	160.514	.315930E-06	.37293 E+10
101	197.640	162.905	.268530E-06	.31136 E+10
102	200.200	165.340	.220410E-06	.25996 E+10
103	202.755	164.616	.195180E-06	.21866 E+10
104	205.310	167.333	.166610E-06	.18291 E+10
105	209.415	168.365	.143100E-06	.15317 E+10
106	213.520	17 .647	.122910E-06	.12826 E+10
107	218.750	173.256	.108320E-06	.10767 E+10
108	223.980	175.564	.919700E-07	.90367 E+09
109	231.990	177.626	.803010E-07	.70332 E+09
110	240.000	18 .738	.701130E-07	.54727 E+09
111	252.000	184.252	.619970E-07	.42759 E+09
112	264.000	187.580	.548210E-07	.33469 E+09
113	276.000	19 .715	.495530E-07	.26674 E+09
114	288.000	193.654	.438920E-07	.21296 E+09
115	300.000	195.865	.396610E-07	.17314 E+09
116	312.000	20 .369	.355370E-07	.14076 E+09
117	324.000	20 .7 1	.326520E-07	.11622 E+09
118	336.000	205.862	.297500E-07	.95955 E+08
119	348.000	20 .052	.27 490E-07	.80287 E+08
120	360.000	212.279	.25 500E-07	.67178 E+08
121	371.445	214.4 2	.231270E-07	.56935 E+08
122	382.890	215.214	.213520E-07	.48254 E+08
123	394.335	217.824	.198160E-07	.41295 E+08
124	405.780	21 .243	.183410E-07	.35340 E+08
125	416.710	22 .579	.171450E-07	.30538 E+08
126	427.640	22 .045	.15 30E-07	.26366 E+08
127	438.045	22 .952	.149570E-07	.22994 E+08
128	448.450	223.929	.139470E-07	.20036 E+08
129	458.860	224.727	.131430E-07	.17573 E+08
130	469.270	225.533	.123410E-07	.15407 E+08
131	478.305	226.346	.116230E-07	.13623 E+08
132	487.340	227.053	.109470E-07	.12045 E+08
133	496.375	227.662	.103370E-07	.10699 E+08
134	505.410	225.177	.976140E-08	.95028 E+07
135	514.450	22 .041	.92 370E-08	.84763 E+07
136	523.490	223.068	.874590E-08	.75607 E+07
137	532.525	224.427	.829620E-08	.67706 E+07
138	541.560	223.723	.786360E-08	.60630 E+07
139	550.595	223.959	.747350E-08	.54494 E+07
140	559.630	23 .139	.71 870E-08	.48979 E+07
141	567.105	23 .274	.670820E-08	.44283 E+07
142	574.580	23 .368	.644400E-08	.40038 E+07
143	582.055	23 .423	.614530E-08	.36296 E+07
144	589.530	23 .441	.586 40E-08	.32303 E+07
145	597.010	23 .426	.559700E-08	.29902 E+07
146	604.490	23 .385	.534540E-08	.27175 E+07
147	611.965	23 .319	.511210E-08	.24756 E+07
148	619.440	23 .230	.489 00E-08	.22552 E+07
149	626.915	23 .119	.468150E-08	.20591 E+07
150	634.390	229.979	.448280E-08	.18880 E+07
151	640.580	229.814	.430630E-08	.17292 E+07
152	646.770	229.636	.413670E-08	.15905 E+07
153	652.960	22 .445	.397380E-08	.14629 E+07
154	659.150	229.242	.381730E-08	.13456 E+07
155	665.340	22 .993	.366700E-08	.12376 E+07
156	671.530	223.700	.352260E-08	.11384 E+07
157	677.720	228.401	.330390E-08	.10471 E+07
158	683.910	22 .98	.325070E-08	.96307 E+06
159	690.100	227.790	.312270E-08	.88582 E+06
160	696.290	227.460	.299970E-08	.81477 E+06
161	701.418	227.108	.289370E-08	.75563 E+06
162	706.546	226.757	.279140E-08	.70078 E+06

163	711.674	22[illegible].4[illegible]6	.269280E-08	.64992[illegible]E+06
164	716.802	22[illegible]. [illegible]55	.259760E-08	.60274[illegible]E+06
165	721.930	225.7[illegible]5	.251580E-08	.55899[illegible]E+06
166	727.058	22[illegible].356	.241730E-08	.51842 E+06
167	732.186	225.[illegible]8	.233190E-08	.48079[illegible]E+06
168	737.314	224.662	.224950E-08	.44589 E+06
169	742.442	224.318	.217000E-08	.41353 E+06
170	747.570	223.955	.209330E-08	.38351[illegible]E+06
171	751.633	22[illegible].575	.202570E-08	.35785 E+06
172	755.696	223.[illegible]99	.196020E-08	.33391[illegible]E+06
173	759.759	222.827	.189690E-08	.31157 E+06
174	763.822	22[illegible].460	.183560E-08	.29072[illegible]E+06
175	767.885	22[illegible].[illegible]96	.177620E-08	.27127 E+06
176	771.948	22[illegible].737	.171880E-08	.25312[illegible]E+06
177	776.011	22[illegible].382	.166330E-08	.23619 E+06
178	780.074	22[illegible].[illegible]32	.16[illegible]950E-08	.22038[illegible]E+06
179	784.137	22[illegible].[illegible]87	.155750E-08	.20564[illegible]E+06
180	7[illegible]0.200	22[illegible].331	.15[illegible]720E-08	.19168[illegible]E+06
181	791.766	21[illegible].965	.146200E-08	.17978[illegible]E+06
182	795.332	21[illegible].[illegible]5	.141[illegible]20E-08	.16844 E+06
183	798.898	21[illegible].251	.137570E-08	.15781[illegible]E+06
184	8[illegible]2.464	21[illegible].[illegible]	.13[illegible]50E-08	.147[illegible]5 E+06
185	[illegible]6.030	21[illegible].557	.129[illegible]50E-08	.138[illegible]E+06
186	8[illegible]9.596	21[illegible].[illegible]9	.125[illegible]70E-08	.12979 E+06
187	8[illegible]3.162	21[illegible].885	.12[illegible]810E-08	.12160[illegible]E+06
188	816.728	21[illegible].558	.11[illegible]160E-08	.11393[illegible]E+06
189	[illegible]20.294	21[illegible].[illegible]35	.11[illegible]10E-08	.10674[illegible]E+06
190	[illegible]23.860	21[illegible].909	.11[illegible]180E-08	.10001 E+06

AFGL LINE FILE OF INTEREST FOR TRANSITION 011[illegible]1 TO 0[illegible]001

BRANCH	LINE	FREQ. (CM-1)	LINE STRENGTH	LINEWIDTH	LOWER STATE ENERGY
P	100	593.83[illegible]	.666E-26	.048	3927.621
P	98	595.21[illegible]	.138E-25	.049	3773.364
P	96	596.59[illegible]	.284E-25	.049	3622.166
P	94	597.9[illegible]	.572E-25	.050	3474.030
P	92	599.37[illegible]	.114E-24	.050	3328.959
P	90	600.76[illegible]5[illegible]	.222E-24	.051	3186.955
P	88	602.1654[illegible]	.428E-24	.052	3048.021
P	86	603.567[illegible]	.811E-24	.052	2912.158
P	84	604.97[illegible]4[illegible]	.151E-23	.053	2779.369
P	82	606.38[illegible]6[illegible]	.278E-23	.053	2649.656
P	80	607.79[illegible]5[illegible]	.504E-23	.054	2523.022
P	78	609.21[illegible]1[illegible]	.897E-23	.055	2399.468
P	76	610.63[illegible]6[illegible]	.157E-22	.055	2278.996
P	74	612.0558	.272E-22	.056	2161.609
P	72	613.48[illegible]8[illegible]	.462E-22	.056	2047.308
P	70	614.91[illegible]6[illegible]	.773E-22	.057	1936.095
P	68	616.35[illegible]3[illegible]	.127E-21	.058	1827.972
P	66	617.79[illegible]7[illegible]	.206E-21	.058	1722.941
P	64	619.23[illegible]8[illegible]	.329E-21	.059	1621.003
P	62	620.68[illegible]8[illegible]	.517E-21	.059	1522.160
P	60	622.13[illegible]6[illegible]	.798E-21	.060	1426.414
P	58	623.5862[illegible]	.121E-20	.061	1333.767
P	56	625.04[illegible]6[illegible]	.181E-20	.061	1244.219
P	54	626.5067[illegible]	.267E-20	.062	1157.773
P	52	627.97[illegible]6[illegible]	.386E-20	.062	1074.430
P	50	629.44[illegible]3[illegible]	.549E-20	.063	994.190
P	48	630.9158[illegible]	.768E-20	.064	917.056
P	46	632.3931[illegible]	.106E-19	.064	843.029
P	44	633.874[illegible]0[illegible]	.143E-19	.065	772.110
P	42	635.3568[illegible]	.190E-19	.065	704.300
P	40	636.8473[illegible]	.248E-19	.066	639.600

P	38	638.33[illegible]5[illegible]	.319E-19	.067	579.011
P	36	639.8354[illegible]	.402E-19	.067	519.534
P	34	641.3356[illegible]	.497E-19	.068	464.171
P	32	642.83[illegible]	.603E-19	.068	411.922
P	30	644.3453[illegible]	.718E-19	.069	362.788
P	28	645.8560[illegible]	.839E-19	.070	316.769
P	26	647.37[illegible]3[illegible]	.959E-19	.070	273.868
P	24	648.88[illegible]2	.107E-18	.071	234.083
P	22	650.40[illegible]7[illegible]	.118E-18	.071	197.416
P	20	651.9349[illegible]	.125E-18	.072	163.868
P	18	653.4636[illegible]	.131E-18	.073	133.439
P	16	654.99[illegible]9[illegible]	.132E-18	.073	106.130
P	14	656.53[illegible]7[illegible]	.129E-18	.074	81.940
P	12	658.0711[illegible]	.121E-18	.074	60.871
P	10	659.61[illegible]	.108E-18	.075	42.922
P	8	661.16[illegible]3[illegible]	.909E-19	.076	28.095
P	6	662.71[illegible]1[illegible]	.609E-19	.076	16.389
P	4	664.2633[illegible]	.432E-19	.077	7.804
P	2	665.82[illegible]	.148E-19	.077	2.341
Q	2	667.3802[illegible]	.743E-19	.077	2.341
Q	4	667.40[illegible]7[illegible]	.130E-18	.077	7.804
Q	6	667.4235[illegible]	.181E-18	.076	16.389
Q	8	667.45[illegible]6[illegible]	.223E-18	.075	28.095
Q	10	667.49[illegible]9[illegible]	.256E-18	.075	42.922
Q	12	667.54[illegible]5[illegible]	.280E-18	.074	60.871
Q	14	667.5974[illegible]	.293E-18	.074	81.940
Q	16	667.66[illegible]5[illegible]	.296E-18	.073	106.130
Q	18	667.73[illegible]9[illegible]	.291E-18	.072	133.439
Q	20	667.81[illegible]5[illegible]	.278E-18	.072	163.868
Q	22	667.9[illegible]4	.259E-18	.071	197.416
Q	24	668.00[illegible]4[illegible]	.236E-18	.071	234.083
Q	26	668.1057[illegible]	.211E-18	.070	273.868
R	0	668.16[illegible]3[illegible]	.301E-19	.078	0.000
Q	28	668.2102[illegible]	.184E-18	.069	316.769
Q	30	668.34[illegible]	.158E-18	.069	362.788
Q	32	668.47[illegible]7[illegible]	.132E-18	.068	411.922
Q	34	668.60[illegible]6[illegible]	.109E-18	.068	464.171
Q	36	668.75[illegible]7[illegible]	.881E-19	.067	519.534
Q	38	668.9[illegible]	.699E-19	.066	578.011
Q	40	669.07[illegible]3[illegible]	.545E-19	.066	639.600
Q	42	669.24[illegible]6[illegible]	.418E-19	.065	704.300
Q	44	669.42[illegible]1[illegible]	.315E-19	.065	772.110
Q	46	669.6065[illegible]	.233E-19	.064	843.029
R	2	669.7263[illegible]	.597E-19	.077	2.341
Q	48	669.80[illegible]	.170E-19	.063	917.056
Q	50	670.0034[illegible]	.122E-19	.063	994.190
Q	52	670.2138[illegible]	.856E-20	.062	1074.430
Q	54	670.4322	.593E-20	.062	1157.773
Q	56	670.65[illegible]4[illegible]	.404E-20	.061	1244.219
Q	58	670.8925[illegible]	.271E-20	.060	1333.767
Q	60	671.1344[illegible]	.179E-20	.060	1426.414
R	4	671.2947[illegible]	.874E-19	.077	7.804
Q	62	671.38[illegible]1[illegible]	.116E-20	.059	1522.160
Q	64	671.64[illegible]6[illegible]	.740E-21	.059	1621.003
Q	66	671.90[illegible]9[illegible]	.465E-21	.058	1722.941
Q	68	672.17[illegible]8[illegible]	.287E-21	.057	1827.972
Q	70	672.46[illegible]4[illegible]	.175E-21	.057	1936.095
Q	72	672.74[illegible]7[illegible]	.105E-21	.056	2047.308
R	6	672.8664[illegible]	.112E-18	.076	16.389
Q	74	673.0445[illegible]	.619E-22	.056	2161.609
Q	76	673.3479[illegible]	.359E-22	.055	2278.996
Q	78	673.6588[illegible]	.205E-22	.054	2399.468
Q	80	673.9772[illegible]	.116E-22	.054	2523.022
Q	82	674.30[illegible]9[illegible]	.640E-23	.053	2649.656
R	8	674.44[illegible]3[illegible]	.133E-18	.075	28.095
Q	84	674.6361[illegible]	.349E-23	.053	2779.369

Q	86	674.97060	.188E-23	.052	2912.158
Q	88	675.3244.	.992E-24	.051	3048.021
Q	90	675.67340	.517E-24	.051	3186.955
R	10	676.0135	.149E-18	.075	42.922
Q	92	676.0426.	.265E-24	.050	3328.959
Q	94	676.41.9.	.134E-24	.050	3474.030
Q	96	676.7873.	.666E-25	.049	3622.166
Q	98	677.17.80	.326E-25	.048	3773.364
Q	100	677.56.20	.157E-25	.046	3927.621
R	12	677.60.9	.159E-18	.074	60.871
Q	102	677.9535.	.747E-26	.047	4084.936
R	14	679.1855	.165E-18	.074	81.940
R	16	680.7732	.165E-18	.073	106.130
R	18	682.364..	.161E-18	.072	133.439
R	20	683.9579	.153E-18	.072	163.868
R	22	685.554..	.143E-18	.071	197.416
R	24	687.154..	.130E-18	.071	234.083
R	26	688.7570	.115E-18	.070	273.868
R	28	690.3637	.101E-18	.069	316.769
R	30	691.975.	.859E-19	.069	362.788
R	32	693.584..	.721E-19	.068	411.922
R	34	695.19.7.	.594E-19	.068	464.171
R	36	696.81...	.480E-19	.067	519.534
R	38	698.43..	.381E-19	.066	578.011
R	40	700.05.8.	.298E-19	.066	639.600
R	42	701.684.3.	.228E-19	.065	704.300
R	44	703.3124.	.172E-19	.065	772.110
R	46	704.94..	.128E-19	.064	843.029
R	48	706.57.3.	.929E-20	.063	917.056
R	50	708.21...	.666E-20	.063	994.190
R	52	709.35.2.	.469E-20	.062	1074.430
R	54	711.49.8.	.326E-20	.062	1157.773
R	56	713.13.8.	.222E-20	.061	1244.219
R	58	714.7791.	.149E-20	.060	1333.767
R	60	716.42.6.	.984E-21	.060	1426.414
R	62	718.07.4.	.639E-21	.059	1522.160
R	64	719.72.4.	.409E-21	.059	1621.003
R	66	721.38.5.	.257E-21	.058	1722.941
R	68	723..3.6.	.159E-21	.057	1827.972
R	70	724.69...	.972E-22	.057	1936.095
R	72	726.35.9.	.583E-22	.056	2047.308
R	74	728.01..	.344E-22	.056	2161.609
R	76	729.68.9.	.200E-22	.055	2278.996
R	78	731.34.6.	.115E-22	.054	2393.468
R	80	733.01...	.646E-23	.054	2523.022
R	82	734.68.1.	.359E-23	.053	2649.656
R	84	736.35.9.	.196E-23	.053	2779.369
R	86	738.02.2.	.105E-23	.052	2912.158
R	88	739.70.2.	.558E-24	.051	3048.021
R	90	741.3772.	.291E-24	.051	3186.955
R	92	743.05.8.	.150E-24	.050	3328.959
R	94	744.73.8.	.757E-25	.050	3474.030
R	96	746.41.0.	.377E-25	.049	3622.166
R	98	748.09.3.	.185E-25	.048	3773.364
R	100	749.7728.	.893E-26	.048	3927.621
R	102	751.45.3.	.425E-26	.047	4084.936

RADIANCE (WATT/CM2*STR) AT VARIOUS TANGENT HEIGHTS

LINE	70 KM (THIN)	70 KM
P 10	.98726E-15	.98726E-15

P	98	.25597E-14	.25597E-14
P	96	.66005E-14	.66005E-14
P	94	.16847E-13	.16847E-13
P	92	.42436E-13	.42436E-13
P	90	.10533E-12	.10533E-12
P	88	.25706E-12	.25706E-12
P	86	.61604E-12	.61601E-12
P	84	.14489E-11	.14487E-11
P	82	.33415E-11	.33405E-11
P	80	.75533E-11	.75482E-11
P	78	.16736E-10	.16710E-10
P	76	.36321E-10	.36203E-10
P	74	.77222E-10	.76634E-10
P	72	.16079E-09	.15546E-09
P	70	.32787E-09	.31827E-09
P	68	.65444E-09	.61698E-09
P	66	.12766E-08	.11457E-08
P	64	.24468E-08	.19756E-08
P	62	.45827E-08	.31229E-08
P	60	.83975E-08	.43861E-08
P	58	.15063E-07	.54224E-08
P	56	.26443E-07	.59377E-08
P	54	.45368E-07	.63035E-08
P	52	.76201E-07	.63479E-08
P	50	.12517E-06	.62595E-08
P	48	.20106E-06	.6[illegible]58E-08
P	46	.31580E-06	.59332E-08
P	44	.48506E-06	.57745E-08
P	42	.72761E-06	.56518E-08
P	40	.10671E-05	.55725E-08
P	38	.15291E-05	.55343E-08
P	36	.21391E-05	.55331E-08
P	34	.29215E-05	.55622E-08
P	32	.38903E-05	.56118E-08
P	30	.50602E-05	.56731E-08
P	28	.64111E-05	.574[illegible]5E-08
P	26	.79106E-05	.58[illegible]97E-08
P	24	.95005E-05	.58765E-08
P	22	.11026E-04	.[illegible]9053E-08
P	20	.12546E-04	.59811E-08
P	18	.13766E-04	.[illegible]E-08
P	16	.14574E-04	.60188E-08
P	14	.14843E-04	.60[illegible]29E-08
P	12	.14461E-04	.59594E-08
P	10	.13335E-04	.58630E-08
P	8	.11447E-04	.57676E-08
P	6	.88364E-05	.56[illegible]32E-08
P	4	.56103E-05	.53737E-08
P	2	.19303E-05	.50517E-08
Q	2	.90798E-05	.56217E-08
Q	4	.16794E-04	.59746E-08
Q	6	.22894E-04	.62[illegible]52E-08
Q	8	.27674E-04	.63879E-08
Q	10	.31[illegible]5[illegible]E-04	.65[illegible]64E-08
Q	12	.32651E-04	.65798E-08
Q	14	.32874E-04	.66149E-08
Q	16	.31801E-04	.66152E-08
Q	18	.29672E-04	.65872E-08
Q	20	.26005E-04	.65322E-08
Q	22	.23481E-04	.64544E-08
Q	24	.19989E-04	.63579E-08
Q	26	.16554E-04	.62463E-08
R	[illegible]	.39343E-05	.52171E-08
Q	28	.13350E-04	.61233E-08
Q	30	.10487E-04	.59930E-08
Q	32	.[illegible]360E-05	.58621E-08

Q	3[illegible]	.6[illegible]092E-05	.[illegible]7[illegible]85E-08
Q	3[illegible]	.4380[illegible]1E-05	.[illegible]E-[illegible]
Q	3[illegible]	.31258E-05	.55469E-08
G	4[illegible]	.21761E-05	.[illegible]4938E-08
G	4[illegible]	.[illegible]40[illegible]2E-05	.548[illegible]9E-08
Q	4[illegible]	.98413E-06	.55147E-08
Q	46	.63962E-06	.[illegible]61[illegible]9E-08
R	[illegible]	.773[illegible]7E-05	.[illegible]49[illegible]8E-08
Q	4[illegible]	.4[illegible]647E-06	.[illegible]7511E-08
Q	5	.25[illegible]43E-06	.[illegible]9221E-08
Q	5[illegible]	.15345E-06	.[illegible]09[illegible]2E-08
G	5[illegible]	.91222E-07	.[illegible]2[illegible]E-08
Q	56	.53052E-07	.[illegible]2118E-08
Q	5[illegible]	.3[illegible]192E-07	.[illegible]123E-08
Q	6	.1[illegible]01[illegible]E-07	.[illegible]92E-08
R	[illegible]	.1[illegible]164E-04	.[illegible]6913E-08
G	6[illegible]	.[illegible]1632E-0[illegible]	.[illegible]5[illegible]3E-08
Q	6[illegible]	.4[illegible]8[illegible]1E-08	.52265E-08
Q	6[illegible]	.[illegible]5522E-0[illegible]	.[illegible]319E-08
Q	[illegible]	.13045E-08	.11576E-08
G	7	.653[illegible]1E-09	.[illegible]1466E-09
Q	7[illegible]	.3[illegible]013E-09	.[illegible]1[illegible]73E-09
R	[illegible]	.14031E-04	.[illegible]8343E-08
Q	7[illegible]	.15357E-09	.[illegible]5139E-09
Q	7[illegible]	.72181E-10	.71697E-10
Q	7[illegible]	.3[illegible]242E-10	.[illegible]E-10
G	8	.14994E-10	.14973E-10
Q	8[illegible]	.60334E-11	.[illegible]6294E-11
R	[illegible]	.16189E-04	.[illegible]9357E-08
G	8[illegible]	.28759E-11	.[illegible]8752E-11
Q	[illegible]	.[illegible]236E-11	.[illegible]2234E-11
Q	8[illegible]	.51[illegible]9[illegible]E-12	.[illegible]1[illegible]88E-12
Q	9[illegible]	.[illegible]967E-12	.[illegible]967E-12
R	1	.17567E-04	.[illegible]22E-08
Q	92	.84679E-13	.[illegible]467[illegible]E-13
Q	94	.33711E-13	.[illegible]3711E-13
G	9[illegible]	.13274E-13	.13274E-13
Q	[illegible]	.51[illegible]54E-14	.[illegible]1854E-14
G	1[illegible]	.2[illegible]188E-14	.[illegible]E-14
R	[illegible]	.[illegible]0143E-04	.[illegible]375E-08
Q	1[illegible]	.78860E-15	.7856[illegible]E-15
R	1[illegible]	.17978E-04	.[illegible]454E-0[illegible]
R	1[illegible]	.17173E-04	.[illegible]284E-08
R	1[illegible]	.15856E-04	.[illegible]9847E-08
R	2[illegible]	.14204E-04	.[illegible]93[illegible]4E-08
R	22	.12349E-04	.[illegible]8556E-08
R	24	.1[illegible]443E-04	.[illegible]7681E-08
R	2[illegible]	.85958E-05	.[illegible]6716E-08
R	2[illegible]	.68987E-05	.55711E-0[illegible]
R	3[illegible]	.53962E-05	.54710E-08
R	3[illegible]	.41176E-05	.[illegible]3779E-08
R	3[illegible]	.3[illegible]604E-05	.[illegible]2993E-08
R	3[illegible]	.22239E-05	.[illegible]2423E-08
R	3[illegible]	.[illegible]5836E-05	.[illegible]21[illegible]E-0[illegible]
R	4[illegible]	.1[illegible]99[illegible]E-05	.[illegible]2214E-08
R	4[illegible]	.74515E-06	.[illegible]2724E-08
R	4[illegible]	.4[illegible]383E-06	.53692E-08
R	46	.32[illegible]8E-06	.[illegible]5[illegible]46E-08
R	4[illegible]	.2[illegible]201E-06	.[illegible]6611E-08
R	5[illegible]	.12569E-06	.[illegible]8[illegible]82E-08
R	52	.76195E-07	.[illegible]9[illegible]23E-08
R	5[illegible]	.45188E-07	.[illegible]8832E-08
R	56	.26214E-07	.56654E-08
R	58	.14[illegible]3E-07	.5[illegible]273E-08
R	[illegible]	.82677E-08	.41867E-08
R	62	.44958E-08	.[illegible]51E-08

R	6[illegible]	.[illegible]9[illegible]7E-08	.[illegible]91[illegible]8E-[illegible]8
R	6[illegible]	.[illegible]2468E-[illegible]8	.[illegible]1[illegible]55E-[illegible]
R	6	.6[illegible]6[illegible]4E-[illegible]9	.[illegible]9772E-[illegible]9
R	7	.[illegible]7[illegible]5E-09	.[illegible]779E-[illegible]9
R	7[illegible]	.1[illegible]529E-[illegible]9	.[illegible]9
R	7[illegible]	.7[illegible]379E-10	.[illegible]3436E-1[illegible]
R	7[illegible]	.34[illegible]98E-10	.[illegible]4779E-1[illegible]
R	7	.[illegible]6[illegible]44E-10	.[illegible]6[illegible]8E-1[illegible]
R	8	.7[illegible]24[illegible]E-11	.[illegible]219[illegible]E-11
R	8[illegible]	.[illegible]19[illegible]E-11	.[illegible]1[illegible]2E-1[illegible]
R	8[illegible]	.[illegible]8[illegible]7E-11	.[illegible]3[illegible]6E-11
R	8[illegible]	.55[illegible]75E-12	.[illegible]8[illegible]72E-12
R	[illegible]	.[illegible]459E-12	.[illegible]88E-12
R	9	.[illegible]6E-12	.[illegible]46E-12
R	9[illegible]	.4[illegible]6[illegible]6E-13	.[illegible]6[illegible]6E-1[illegible]
R	9[illegible]	.[illegible]196E-13	.[illegible]1[illegible]6E-13
R	9[illegible]	.6[illegible]977E-14	.[illegible]977E-14
R	9[illegible]	.2512[illegible]E-14	.[illegible]5[illegible]26E-14
R	10[illegible]	.9[illegible]6[illegible]3E-15	.[illegible]3E-15
R	10[illegible]	.[illegible]919E-15	.[illegible]919E-15

TOTAL FOR [illegible] LINES = .[illegible]E-[illegible]

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